IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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To the Safety, Mechanical, Combustion and Electrical Engineers, Iron and Steel Industry, United States and Canada:

Gentlemen:

You are concerned with the problems of industry and they are many.

Did you ever stop to think that most of your troubles might be solved, if you had the courage and the confidence to take these troubles to the A. I. & S. E. E. and have them analyzed and then discussed by your fellow members of your Association.

Surely the membership can answer your question with twenty years experience. What other agency—what other medium in the country is so well equipped as your Association, made up as it is, with representation from the largest corporation in the world down to the smallest plant.

Your Association is able if you will let them, to solve any engineering problem that might arise in your plant.

Ask yourself this question, "Have I taken advantage of the opportunities that the A. I. & S. E E. affords its membership?"

In all probability you will have to admit you have not.

The A. I. & S. E. E. is anxious to help you secure the knowledge that you are so industriously seeking.

Make up your mind to use the Association to the fullest extent.

Trusting that you will allow us to serve you, believe us to be

Your most sincerely,

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS.

EDITORIALS

ELECTRIC DEVELOPMENT GIVES AMERICA INDUSTRIAL SUPREMACY*

IN the latter part of the nineteenth century, a new power agency—electricity—came into existence.

Waterpower increased the prosperity of the nation because it was more than manual labor; steam power caused a further increase because it was superior to waterpower; and electricity has still further added to our national wealth because it represents a marked advance over directly-applied steam power.

It has greatly increased the production per worker; it has multiplied our resources by permitting us to accomplish many things that were formerly impossible; it has improved transportation facilities, both urban and interurban; it has transformed our cities into veritable fairylands; and it has raised the standard of living to unprecedented levels.

Its use has, in fact, enabled the United States to gain the industrial supremacy of the world.

Most European countries are far behind us in electric development. Our superiority in this respect is largely due to the fact that in America electric light and power systems grew up without interference on the part of governmental authorities, and, while an excellent method of regulation by state commission was early introduced here, there was nothing in this country to retard electric progress.

Our workmen now have at their disposal an average of 3¾ horsepower per worker, which is about double that available to the workmen of England, the next most highly developed nation. Herein lies the secret of why "The American workmen are able to enjoy better standards of living than any other working people in the world"

It has taken Europe many years to realize the immense gain in production that American industry has secured through the use of electric power, but she is now fully alive to the situation and we can look for rapid electrical developments over there.

But in the meantime, American progress is showing no signs of halting.

*Extract of speech delivered by G. E. Tripp, before The Congress of American Industry, September 14, 1926.

WHERE ARE YOU GOING?

This is a question many of us are unable to answer. We seem to be on our way, but the road leads us nowhere Success always seems to be just at the end of the road we are tramping each day, but nightfall finds us where we started at the dawn.

Too many of us have single track minds, and we allow habit, precedent, tomorrow, to dominate our acts and our deeds.

The line between success and defeat is so thin that a step either way will sometimes decide our future.

Corporations, large industries are filled with just as much dead and drifting wood as perhaps the obsolete plants, and when some leader awakes and puts in motion, new thoughts, new blood, there is always the pack at his heels, but the leader wins.

The Engineer is too well satisfied with his lot and his "lot" is little.

He is satisfied to be left alone and that is perhaps why he does not know where he is going. The Engineer to be successful, must forget some of his engineering and get acquainted with what is going on, outside of his immediate realm.

Engineers, wake up, know your neighbor, get started somewhere, anywhere so it's headed towards the avenue called Success.

INSPECTION TRIPS

One of the engineering services that the Association is able to offer its many members is the opportunity to inspect, at regular intervals, the constant and increasing improvements that are taking place in the Iron and Steel Industry today.

It goes without saying that the educational advantages offered on these trips are such that no steel engineer can very well afford to miss them. Granted, of course, that he is anxious to learn of the progress in the industry in which he is most interested.

Also the fact that the steel companies are more than willing to open wide their doors for the engineers indicates that they, too, realize the advantages of a closer form of co-operation than perhaps existed in the years past.

Mr. L. R. Custer, General Manager, Cambria Plant, Bethlehem Steel Company, Johnstown, Pa., is to be commended for his liberal attitude in this connection.

Here is four new rolling mills which represents millions of dollars in investment; the installation is just months old, and Mr. Custer offers us the privileges of a personal inspection. What else is this if not co-operation. At least 500 executives and engineers have accepted the invitation to the trip to Cambria on Saturday, September 25th, 1926.

The Association of Iron and Steel Electrical Engineers wishes to acknowledge at this time their sincerest appreciation to Mr. Custer for the spirit he has shown in allowing the membership to inspect four of the most modern bar mills in the industry today.

It is with the deepest pride that we list among our very good friends some of the largest companies in this country. They have ever been willing to leave nothing unturned to make our Society such a successful one. Inspection trips have been conducted at some 30 odd plants in the past and all have been highly successful.

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*Discussion: Addition to Rolling Mills at Steubenville Plant, Wheeling Steel Corporation**

By MEMBERSHIP

S. S. Wales†: Before we start the discussion, I would like to say that the electrical man, of course, is naturally biased in favor of the electric motor, but we must be familiar with everything that comes up in competition; not only familiar with it, but we must view it fairly as an honest competitor and not as an enemy. If the uniflow engine can meet us on our own ground and beat us on first cost, repairs, overhead and upkeep, then we lose. If it can nearly meet us, it stimulates us to do better than all of our future investigations along that line.

I have quite a few people I want to call on. The first being Mr. H. C. Siebert, Combustion Engineer, of the Bethlehem Steel Company. In 1920, Mr. Siebert made the most elaborate set of tests that had been made up to that time, and I do not know of anything that has yet surpassed, on both steam and electric drives. If anybody wants to refer to that, it can be found in our Proceedings of 1920. I will call on Mr. Siebert to discuss this subject.

H. C. Siebert‡: In view of the fact that Mr. Conway and I are good friends and in view of the fact that I have worked on papers of this nature in the past, I am very much interested in his paper. I think it is an unusually complete and thorough presentation.

The thing that strikes me is that our comparison, of course, must be economic, and that comparison is because it leads right up to the question: "What is the final cost per ton of product rolled?"

From Mr. Conway's presentation it is apparent that the engine has a water rate of about 16 pounds per indicated horsepower hour. Now that, compared with the ordinary reversing slide valve engine, running non-condensing, has a water rate of 45 pounds, so that this engine is practically one-third in steam consumption as compared to the ordinary old-type reversing slide valve engine.

Compared with the modern twin tandem-compound, single lever controlled engine, which is the next link in advancement prior to the uniflow, the relation would be about 16 to 22 or 23 pounds, still a very decided reduction in steam requirement.

Now, as Mr. Conway has pointed out, there are other factors that enter into the proposition and it is a matter that requires a very detailed study and analysis of local conditions to enable one to determine whether the electric drive or the steam drive is the thing for him to do. The basis of comparison in the past has been, of course, the old, wasteful, simple reversing engine, which had a water rate, as I said before, of from 45 to 50 pounds per indicated horsepower hour. Now, if we have such a basis of comparison for an electric plant which will deliver a kilowatt hour on 14 or 15 pounds, there, of course, the factor is overwhelmingly in favor of the electric proposition.

But we have another parallel, if we are dealing with an engine of the type that has been brought out.

I think the data presented is very interesting. I want to congratulate Mr. Conway for the presentation of it, and everybody in the Society should extend a vote of thanks for the privilege of being able to publish it.

S. S. Wales: We thank Mr. Siebert for his comments. We have several men here from the Bethlehem Steel Company that I want to call on, who have probably valuable information on this point. The next will be Mr. F. O. Schnure, the Electrical Superintendent of the Bethlehem Steel Company, at Sparrows Point. I understand that he has a mill, electrically driven, of very large capacity. I would like to call on Mr. Schnure.

F. O. Schnure†: Mr. Chairman and gentlemen. I don't know that I have anything to offer of interest on the subject of mills. I didn't bring any data along that would throw any light on the subject; that is, in comparing the steam and the electric drive. I will say, however, that in our blooming mill I believe the average power consumption per gross ton of finished product rolled runs about 17 or 18 kilowatt hours per ton. Translated into pounds of steam per hour, that is somewhat less than 300.

In our particular case at Sparrows Point we have a plant that is spread out considerably. To adapt steam drives to our mills would mean individual boiler plants at practically every mill. We are 100 per cent. electric plant so far as main drive is concerned, and I don't believe the question of steam drive will ever come up for that reason.

D. M. Petty‡: I feel that we are to be congratulated on having such an excellent paper in our proceedings for reference. I am very doubtful in my own mind, without giving any figures which will substantiate my opinion, if, in any newly laid out plant today, that steam engine driven mills of large capacity would be considered. However, in existing plants where steam boiler and condensing water conditions, as well as fuel conditions, are favorable, there is no reason why anyone should scrap a good steam engine for the sake of putting in a good motor. The question always comes about as to whether we shall scrap an old steam engine and put in a new steam engine or a new motor, so that it seems to me that even if the uniflow engine was capable of effecting economies in rolling steel that would approximate the motor, it would be doubtful

*Presented at 22nd Annual Convention, June 7-11, 1926.
†Chief Elec. Engr. Carnegie Steel Co., Pittsburgh, Pa.
‡Comb. Engr., Bethlehem Steel Co., Johnstown, Pa.

†Elec. Supt., Bethlehem Steel Co., Sparrows Point, Md.
‡Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.

as to whether the steam engine would be put in, particularly inasmuch as the replacing of an old steam engine would usually mean that the boiler plant and condensing plant would have to be renewed at the same time. For that reason, the question as to whether or not we shall use steam engines or electric motors on mills almost always resolves itself into a discussion of the particular local condition at that particular mill. It may be different for different mills in the same plant. So that while most of us feel that in general the electric drive is to be preferred, I think there are one or two other factors in addition to economy that causes this feeling to exist in minds of the management.

In general, it is easier to keep the motor room and mill clean when electric power is used than when steam engines and boilers are used. Electric power lines are easier to conduct around the plant and keep in good condition than steam lines and water lines. So that the morale of the plant, in general, is better with electric power than it would be with steam power. I think you will find the extreme in that line over in Mr. Ford's plant in Detroit. I understand the question of cleanliness there has been carried to the nth degree, and I believe we will see more and more of the idea of cleanliness introduced into our mills. Some people say it is foolish, but I believe there is a considerable amount of merit in keeping things clean. My own personal observation is that clean motors and clean electrical apparatus do not break down. Now, maybe clean engines and clean boilers do not break down. The best answer along that line, I think, was given in 1920 by Mr. Shover. Since he is not here, I think I will use his answer to this question of steam versus electric drive. It is, that the valves, condensers, etc., can be made to deliver certain things, economies may be kept right up, but they aren't because the valves aren't kept set properly and the vacuum isn't always kept as low as it should be, and the steam pressure isnt always kept up as high as it should be, whereas the electric motor either runs right or shuts down.

I feel that the question of 1926, however, is no longer a controversial one in our proceedings, and this meeting is no longer heralded as "Steam vs. electric drive." So far as I can remember, that question was settled way back in 1920, and we are now very glad to hear from the steam engine fellows with anything they have to offer. (Laughter.) It is just a point of history; and we will let posterity take care of the future.

S. S. Wales: Mr. Petty brought up a good point that just as long as an electric motor runs at all, it is running at nearly its original efficiency. The case is very obvious that any defect that impairs a motors efficiency will shut it down, while the cylinder or valves of an engine, because wear in these ports are harder to keep track of, may gently affect the efficiency without reducing its output.

Now I am going to break over into another line. I understand that the General Electric does not build engines, but they build turbine driven generators, and I am going to call on Mr. Umansky, of the Engineering Department, General Electric Company, Schenectady, N. Y.

L. A. Umansky†: May I be excused from making the usual complimentary (and well deserved in this case) remarks regarding the paper just presented, and may I start directly with asking a few questions? A definite answer to them will undoubtedly throw some additional light on the subject.

My first question will refer to the steam consumption per ton of steel. I believe it to be very important, when comparing the power consumption for rolling steel at different mills, or with different kind of drives, to keep in mind the several possible ways of expressing this consumption. We may talk of so many pounds of steam, or of so many kilowatt hours per gross ton (2240 pounds) or per net ton (2000 pounds) of steel; again, we may refer this consumption per one ton of material rolled (ingots) or per ton of the finished product (blooms). Most of the published data giving power consumption for electrically driven reversing blooming mills give it in terms of kilowatt hours per gross ton of blooms. Mr. Conway's data express this specific consumption in terms of pounds of steam per net ton of ingots. Assuming an average yield for a blooming mill at 91 per cent., Mr. Conway's figures should be increased by approximately 23 per cent. if they are referred to one gross ton of finished product.

It should be also noted that the specific power consumption given by Mr. Conway covers a relatively short period of time (one hour or less) during which the actual rolling took place. Most of the published records of the electrically driven mills refer to the average monthly or yearly consumption, and therefore include standby losses as well as periods of light rolling. Naturally, the monthly average consumption should be—and is—higher than the average for one hour of active rolling, and this fact applies to both, electrically and steam engine driven mills. If anything, the gap between the two kinds of "average values" should be wider in the case of a steam engine with a boiler plant on account of condensation losses during the standby periods.

If we compare Mr. Conway's figures for steam consumption with other similar data published at various times we will note that they seem to be considerably lower than any result heretofore obtained. For instance, Mr. H. C. Siebert presented, in 1920, before this Association, a very interesting discussion on the subject "Steam versus Electric Drives" (see Proceedings of A. I. & S. E. E., 1920, page 35). On Figure 11 of his paper Mr. Siebert has tabulated numerous test results made on steam driven blooming mills. We may take the data corresponding to the compound condensing steam engines, and may plot them by circles on a curve sheet, against the corresponding elongations—disregarding for our purpose the single expansion and non-condensing drives.

We may also refer to the very interesting paper presented in 1914 by Mr. Karl Nibecker (then steam engineer of the Youngstown Sheet and Tube Company), which paper was read before the Engineer's Society of Western Pennsylvania. Mr. Nibecker described some very complete tests made on a high grade twin compound 46"x76"x60" reversing steam

†Engr., General Electric Co., Schenectady, N. Y.

engine driving the 44" blooming mill and operating at 160 pounds gauge and 28" vacuum (actually 25" vacuum was recorded in the low pressure cylinder). We may plot Mr. Nibecker's test results by triangles on the same curve sheet. It should be noted that Mr. Siebert's and Mr. Nibecker's data are expressed in pounds of steam per one ton, gross, of ingots. Therefore, the yield of the mill should be taken into account in figuring out the steam rates per ton of blooms.

Mr. S. Kneass, Jr., steam engineer of the Youngstown Sheet and Tube Company, made the statement (see Proceedings A. I. & S. E. E., 1921, pages 141-142) that their 44" blooming mill engine (the same engine that was tested by Mr. Nibecker in 1914) averages 575 pounds of steam (160 pound gauge, 25" vacuum) per gross ton rolled, for elongation 7; we may mark this point with a cross on our curve sheet.

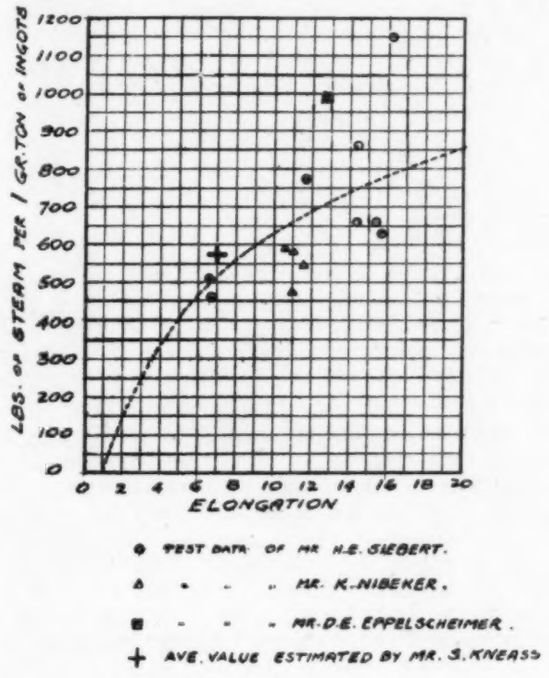


FIG. 1.

I cannot refrain from referring to another very interesting steam consumption test made by Mr. D. E. Eppelscheimer, steam engineer of the American Rolling Mill Co., Middletown, Ohio. Mr. Eppelscheimer found it possible to segregate a battery of boilers supplying steam to a 55"x60" twin-simple steam engine driving their 40" blooming mill and to measure the boiler feed water. There is no question that such a method is the most reliable one for steam tests. The tests lasted for 17 hours and the average rate (see Proceedings A. I. & S. E. E., 1920, page 50) was 1520 pounds of steam per gross ton of ingots. This reversing engine was exhausting at 5 pound back pressure to a low pressure turbine, running with 28" vacuum. Mr. Eppelscheimer credits, therefore, the steam engine with about 400 pounds steam per ton and figures out that the fair charge against the blooming mill is 1120 pounds of steam per one gross ton of ingots. If we assume that instead of the single expansion non-condensing engine, a compound engine with 26" vacuum were used, then (all other conditions being equal) the calculated water rate would be approximately 1000 pounds per one gross ton rolled. I have also marked this point on the curve sheet; this point is very interesting as it shows how much higher is the actual steam consumption as compared with the test results covering but a few ingots.

On the basis of these several tests it is possible to plot an average curve giving the steam consumption per one gross ton of ingots. For elongation 11 the curve gives a rate of approximately 650 pounds per ton.

Now Mr. Conway's tests give a steam rate considerably lower than any other test heretofore published. I do not want to question the accuracy of Mr. Conway's tests but I am very anxious to learn how Mr. Conway himself explains such radical reduction of steam consumptions. After all, even the builders of uniflow engines claim that the economy of their machines is due to reduction of condensation losses. It can hardly be expected that such losses may amount to more than, say, 15 per cent of the steam consumption of a conventional engine. This Association should be very interested in any information that will explain, in a convincing way, why and how the described steam economies were obtained.

My second question will be considerably shorter. Mr. Conway justifies the use of a flow meter for measuring steam consumption during the tests by the fact that the engine consists of four double acting cylinders. This, in Mr. Conway's opinion, creates an almost constant demand and therefore contributes to the accuracy of the flow meter. I cannot subscribe to the correctness of such a statement. If the reversing blooming mill engine were consisting of not four, but of 24 cylinders, even then the steam flow to the engine would be of a pulsating character simply because the power demand at the mill coupling is of such nature. With rolling passes lasting one or two seconds (or even less), with the necessity of plugging and reversing the steam engine, the power demand cannot be, and is not, uniform and therefore the flow of steam to the cylinders should be of the heavily fluctuating kind.

In other words, if Mr. Conway's flow meter read correctly, it is hardly due to the fact that the steam engine consisted of four cylinders but was due to some other facts. I would like to know, therefore, what arrangements were made to insure the accuracy of the flow meter.

My third and last question will be of a more general and broader nature. After all, the most interesting comparison between the different types of drives is not how much steam or electric power either type consumes, but how many dollars and cents the operators must spend in either case for reducing ingots to blooms. It should be admitted that the steel mill electrical engineers published some very exhaustive data tabulating all expenses for electrically driven mills; anyone interested in this subject will find a wealth of information in the Proceedings of this Association. Whoever claims

that the uniflow steam engines are as good, or better, than electric drives for reversing blooming mills should be expected to publish a similar set of data. Do not stop after telling the consumption of steam per ton of steel, but supplement this information by records of cost of maintenance, of repair bills and of other operating expenses. Last, but not least, give a statement of the amount of Sunday work required to keep the drive in good shape; give records of hours of delay and therefore the lost tonnage due to breakdowns or other failures (if any) of the mill drive. No record is complete, no true comparison is possible unless such data are made available and are published. The electrical engineers have done their work in this respect. It is now up to the steam engine operators or builders, if they want to convince anyone that their type of drive is the best, to collect and publish a similar set of statistical records.

J. M. Spitzglass*: I am very glad that I came in just in time.

Now, if you will remember, (some of you whom I see here today), I told you yesterday that I simply love to hear a fellow tell me that I am all wrong, because then I have the chance to convince him. If he goes away and thinks I am wrong without telling me so, I can never do anything to convince him.

I do not blame this gentleman for what I just heard from him, because he is not a flow meter man. He does not know the difference between a fluctuating load and a pulsating load. I don't blame him for it at all, because if a fellow is interested, that is sufficient; that puts him a good deal higher, in my estimation, than many of those who are using flow meters and are not interested in their performance. He is interested in that, and he has heard that the flow meter is not accurate when there is something going up and down.

First, let me give you the principle briefly. The flow meter is based upon the relation of pressure to velocity, and nature has provided that one is proportional to the square of the other; that is, if we call the pressure one unit when the velocity is one, the pressure becomes four units when the velocity is only two, and so on.

What does that mean? If you have to compare quantities consisting of units, say dollars and cents or pounds and tons, then you accumulate those units evenly, and it does not make any difference what kind of a step you take, you add them up and they are all the same. But when you have a case where one quantity is based upon information that is obtained from another one that is fundamentally different, in a different plane so to say; then, in order to translate it from one into the other, you have to put the two on an equal basis. And here is what happens in the flow meter with what we call pulsating flow. We will cover that end of it first.

A pulsating flow is formed when there is a sudden stop of supply at regular momentary intervals; as, for instance, the cut off of a steam to the cylinder of a reciprocating engine. When there is no appreciable capacity between the orifice plate and the engine proper, the flow through the orifice stops at the same moment. If the engine takes steam half of the time, the flow changes from 100 per cent to zero several times each second. Due to the inertia of the mercury column and the moving parts of the recording mechanism, the registration of the instrument does not correspond to the 50 per cent average of the flow but to the 50 per cent average of the differential pressure. As explained before, the 50 per cent average of the differential pressure is equivalent to 70.7 per cent of the flow, and in such case the meter reads 41 per cent high.

Stated technically the recording mechanism should collect and register the average of the square roots of the momentary differential pressures. Due to inertia the mechanism registers instead the square root of the average differential pressure, which is always higher than the average of the momentary square roots of the same differential pressure.

The remedy we offer for this defect is to break up the harmony and diminish the amplitude of the pulsations between the orifice and the engine proper. We require a considerable capacity in pipe or receiver volume between the orifice and the engine. We insert one or two restriction orifices in that line so that the flow through the orifice does not stop entirely at the cut-off of the engine. The sharp pulsation of the flow are eliminated, the variation in the height of the mercury column becomes much smaller and more gradual, so that an electrically operated instrument, having no inertia of moving parts, actually registers the momentary square roots of the corresponding differential pressure.

At times objections are raised to putting in additional restrictions in the line. We have had cases where people complained that it costs money to restrict pressure. So, fortunately, in the case of steam it doesn't matter, because even if you restrict the pressure, the heat is still there. Even in the case of gas we have found that it is advantageous to restrict the pulsations, or at least diminish them as much as possible. I compared it once, when an objection was raised in the case of gas, to the village blacksmith, who has the bellows take in a puff once in a while, still he maintains a straight flow of air on the fire. The same should be true with the reciprocating engine. Follow the practice of the village blacksmith and see that you cut out the effect of those pulsations as much as possible.

Now when it comes to fluctuating flow, that does not effect the accuracy of our meter. The electrically operated flow meter follows the variation of the mercury column moving slowly up and down. The meter has time to register the variations, and there is no question about the accuracy. We will guarantee the meter to have results accurate on a fluctuating flow.

That much for the two, for the pulsating flow and the fluctuating flow. Fluctuating means there is a reasonable time, it may take a minute or two minutes. When we talk about pulsating flow, we talk about so many times in a second; then with restriction, we cut the effect out. But the main thing that strikes me here is that the last speaker's objection is entirely on the wrong premises. As I understand it, this gentleman was worrying about the steam figures being too low. Now, you will

*Engr., Republic Flow Meters Co., Chicago, Ill.

agree that the pulsating flow can only make the meter read high and that is all there is to it. How do you account for that?

So really, after spending a good deal of last evening reading Mr. Conway's book on this subject, I could not find anything wrong there, and I would recommend taking his figures as they are. I thank you, gentlemen.

S. S. Wales: We are very fortunate to have had Mr. Spitzglass come in just as he did, I think. We have certain pioneers in the field who we think have a lot of nerve.

L. A. Umansky: I want to ask you just in a few words as between the pulsating load and the fluctuating load as defined by you. In the reversing steam engine you may have just uniform input of the steam during one revolution only, but the nature of the load is such that you have actually a pulsating load and not a fluctuating load, because you may have reversing occurring in about two or three seconds, and such kind of a proposition by no means follows your definition of a fluctuating load at all; it is purely and simply a pulsating load. If you believe a flow meter would read wrong on a pulsating load, then we have reason to believe that the readings of a flow meter for taking steam from a reversing steam engine, regardless of the make, will not be accurate.

J. M. Spitzglass: It will either read accurately, if you put enough restrictions in, or it must read high, by nature; it cannot read low. The square root of the average is always higher than the average of the square roots.

L. A. Umansky: If it reads high, we have to look for another good explanation of why the tests made on uniflow engines show so much less power consumption than the tests made on other engines. That is something that I wish Mr. Conway would explain.

S. S. Wales: As most of us do not know what this is all about, suppose we call it a draw.

Any man who can do something in this world for the first time, deserves a lot of credit, whether it is discovering America or building a reversing uniflow engine, and we would like to call on Mr. Fennell of the Nordberg Company to tell us something about this engine.

Mr. Fennell†: This uniflow engine that we have down at Wheeling is something that we have gone through quite a siege with, but we are happy to say that it is successful and that it is practically doing better than we thought it would. Of course, everybody in the steel industry at one time had the idea that the thing was going to go bad, and we thought so too, but we had just grit enough to stick and win.

I was down the other day to see this machine myself, so that I could talk to you people intelligently about it, and I don't believe that there is a better specimen or a finer running engine—that is our opinion of it—in a steel mill anywhere.

Now, then, how did this thing start, all of this? The first uniflow engine that was put in a steel mill in this country was in Youngstown, and Mr. Campbell brought Mr. Lief Lee to Milwaukee to see Mr. Nordberg, who had a reputation at that time of being one of the best and most efficient engineers on steam in the United States—Professor Carpenter paid him that compliment and it is in the Transactions of the American Society of Mechanical Engoneers—so that Mr. Campbell brough Mr. Lief Lee in and said to Mr. Nordberg, "We want to buy two uniflow engines."

Mr. Nordberg said, "Well, will you pay the price?"

He said, "Yes, if they don't cost too much."

So we put those in. But Mr. Nordberg said, "Don't talk to me about price; I know nothing about it; I will tell you what the engines will do."

Now, those engines were installed. They were placed in operation in 1916 and they have been running for ten years. They went through the War period, running 24 hours a day rolling steel, and they never faltered a minute. I went in that plant two weeks ago and I met Mr. Rathburn, who is the master mechanic there, and has been in constant touch with these engines ever since they were started in operation, and he said, "They made a barrel of money for us, and the repairs on those engines in ten years haven't amounted to more than one crank pin and one main bearing."

I said, "I don't believe you."

He said, "That is the honest truth."

I said, "What would you do tomorrow if you wanted to drive these Morgan mills?"

He said, "I would do the same thing as we did before."

Now, there have been no accurate tests made on those engines. They are driving what they call a bar mill and a merchant mill and it takes more power per ton of steel to do that than it does to do the work under discussion here.

Mr. Windsor, our Chief Engineer, and the writer have visited and sold practically the majority of uniflow engines that are in steel mills in this country, and we began to discuss, argue and reason out the uniflow engine for a blooming mill, and it took us one year and a half to reach a decision that we wanted to do it.

When we decided to do it, then we had to find somebody who had nerve enough to let us try and experiment on them.

There was quite a prominent engineer, Mr. Stoop, at that time with the Whittaker-Glessner Company, —and he still is.

Mr. Stoop, when I first met him, was at work on rebuilding the Whittaker-Glessner Tin Plate plant in Wheeling. We discussed the matter pro and con and were allowed to lay before him a layout involving the application of Uniflow Engines. Uniflow Engines were finally purchased for Mill drives as well as for Power. We thereby established ourselves through this installation, later with Wheeling Steel Corporation.

Those engines are running today, running nicely and making a lot of money for them, and rolling more economically than a corresponding plant they buy electricity in, and it is running non-condensing.

†V. P. Nordberg Engine Co., Milwaukee, Wis.

Now, men, the Wheeling Steel Corporation came to the point where they wanted to do something at Steubenville. This was back in 1921 and 1922, and we were in the midst of a panic and money, as you know, was a little scarce, and we didn't have enough to go out and bite off a great, big chunk. They had to take this plant and make additions to it, so it could be the economic thing to do. All they were interested in, and they told us so plainly was, "What will it cost us from the coal pile to a ton of steel on the car, so we will know whether we can get our money out of it. We want cheapness and the most economical unit to roll a ton of steel."

I said, "Well, it behooves you to investigate thoroughly both channels. If you put in a uniflow engine under the same economic conditions, high steam pressure and high super-heat and good vacuum, as you will the turbines; spend as much money on your boiler plant as you will for the turbine. It will not have to be quite as large with the uniflow engines as it will for the turbines, because we take the steam direct from the boiler direct to the engine, and you have to go from the boiler plant through one conversion into the turbine, the flywheel set and then another system on to the rolls," I said. "You have several conversions," I said, "We will take less money to put it in and when you wind up I believe"—this is what we believed, we had no experience to back us up at that time—"that the pounds of steam fired in the boiler through the uniflow engine will not be any greater per ton of steal than going around through the other way," and, further, "I believe we can save you half of your money."

They said, "You have that opportunity if you can do it."

We started these negotiations along in March and we ding-donged at this thing until December. I know that the electrical profession had every opportunity during that time, and I think that Mr. Siebert himself had occasion to study and see this situation also. Eight different studies were made to determine upon what was the economical thing to do in that plant. Their engineers figured it out, schemes 1, 2, 3, 4 and on up to 8. We first said, "We will leave the plant like it is and just add in the continuous blooming mill and some power engines and let everything else go and fix our boiler plant." And then, "Well, instead of putting in some engines to make direct current, we will put some turbines in and put in a motor generator set and buy that current," and so on like that. So that everybody had an absolute chance at this thing, consisting of two 8,000 kilowatt generators, plant and everything, using motors on both the continuous mill and the bloomer.

At this time I wish to say that these comparisons were made on the basis, not of our guarantee, but all of these comparisons that we made. We said, "Supposing we fall down, then we would be in a mess," so we actually figured in these comparisons against the electric drive, about 400 to 450 pounds of steam on the bloomer instead of what we guaranteed. We didn't say anything about what we were going to do until we knew where we were

Now, we are glad to see that this thing has come out in the way that we guaranteed that it would. That engine has been running now for some time. It is finely built, it has force-feed lubrication on it; not a bearing on the engine, crank pin or crosshead pin has had a wrench on it since it was started, and it is running every day. One day during the troubles which we had there was some trouble in the steam, and the safety attachment on the engine stuck and the throttle valve stuck, and the man on the pulpit couldn't stop it and the engine ran away. One of our men was there. That was when we were having some of these difficulties which have been mentioned. The engine got up to a speed, possibly, of 200 or 250, we know, until our man went over to the boiler room and closed the valve and shut off the valve at the main point.

The engine hasn't been moved. You cannot tear it up. I understand that the engine today has rolled as high as 180 to 190 tons of steel per hour, and I believe the steam consumption on the whole plant today, I do not know the figures, but Mr. Conway possibly can give you that, but the total steam in that engine, producing 50 to 60 and 70 per cent more steel than we guaranteed, is less than 400 pounds per ton.

We didn't know what it was going to do, but we knew that a uniflow engine ordinarily had a 100 per cent overload with an increase of ten per cent in its economy, at its best load, and 100 per cent overload continuously, so we felt sure that that would be done.

Now, the best way you can get information out of us is to ask us questions and we will try to answer them. I can stand here and talk to you and tell you the good things about all of this, because I am enthusiastic for the Nordberg Company. I have been with them a long time and I think that these engines in these steel mills have a chance. It is not a panacea for all the ills, but it has its applications. And in 1920 it wasn't known; it wasn't until 1922 or 1923 that we got out of the woods. Now we are in a position where we can say to you, and each one of you, that we can do these things, we have done them; we don't have to come to you and say we think we can do them. We have the facts to lay before you. We have an engine in the Republic Iron & Steel that develops and averages 16,000. That engine is running, and it is not dirty. The fellow sits down in his chair, the floor is clean, and that engine is just as clean as it can be. That engine is thoroughly enclosed and has force feed lubrication. That is the thing we are recommending to the steel mill. It doesn't make any difference about the dirt, the man can wipe it all off just as clean as any electrical plant that we know of, and we are ahead on the investment.

As nearly as I can get at it, a steel plant laid out today with a clean piece of ground to start with, take your choice of the electric or the other, we say the uniflow engine should take the big gobs of power, the bloomer and the continuous mill, and the electric should take all the other things where these little driblets and the other things of that kind come in That is the thing, the big steam load. We advised these people up there to run only three steam pipes, and we used a very high velocity, and I told them at that time, with great, big receivers at these engines, those receivers have about five

times the volume in the receiver as the cylinders take in one revolution, so the pulsations in the line 100 feet back are practically nothing without the obstructions necessary, but for safety measures we put them in. We do that because we have a volume of steam stored there for one revolution in those receivers, and when you transmit superheated steam with a high velocity through a small pipe, highly insulated, and have a great, big receiver at your engine, you are getting a minimum of loss, a very short drop, and you are not wasting much steam.

We feel very proud of what we have done.

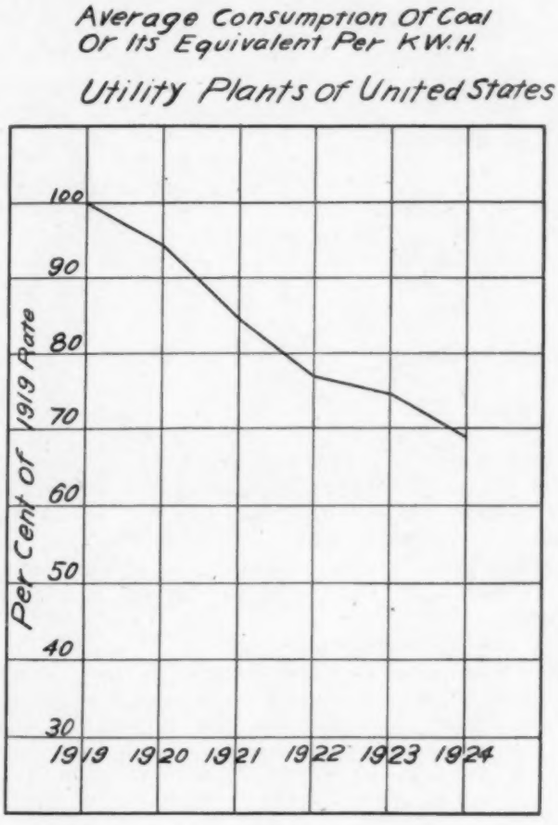


FIG. 1.

G. E. Stoltz*: I am a little rusty on this subject. During the last ten years we have had a number of meetings on this subject in which a number have taken part and these meetings in the past have been taken seriously. Considerable has been said on this subject both by steam engineers and electrical engineers for and against electric drive, but in spite of what has been said in these discussions there is a very definite trend toward electric drive.

I do not believe what we may say either as a steam engineer or an electrical engineer, has a great deal to do with what the trend will be. If electrical apparatus is installed in certain mills, or a steam engine is installed, I believe that the operating engineers come to their conclusions from the results that are actually being obtained in the plants.

*Engr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

I don't believe that Mr. Conway in any way, or his company, want us to assume that they advocate steam drive throughout. They are negotiating for electrical apparatus to drive large mills and I believe that in general indicates their future policy.

There is one thing we must take into consideration when we discuss this subject today, and that is that the economy of a steam turbine plant is much better than that obtained several years ago when electrification in the steel industry was being introduced. An analysis of government reports that are made from average power station operation indicates that during the year 1924 the fuel per K.W.H. generated was only 68 per cent of that required in 1919. The shape of the curve in Figure I indicates that we should expect still greater economies in the future as the lower part of the curve gives no indication of flattening.

About 150 years ago Watt improved the atmospheric steam engine and used steam pressure of ten

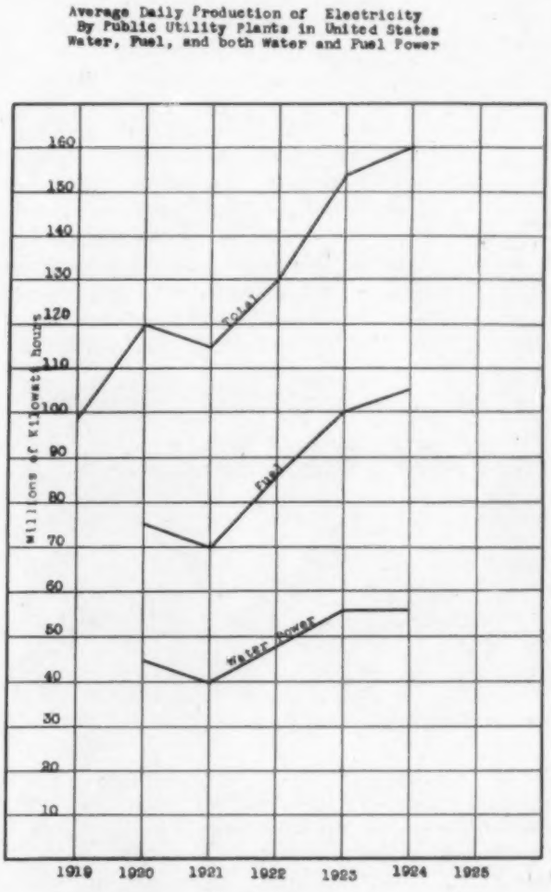


FIG. 2.

pounds per square inch. This was considered quite a step at that time and ten pounds was looked upon as high pressure. From time to time steam pressures have been increased through such values as 50, 100, 150, 200, 250 pounds per square inch, and in recent years 350 pounds has become common for turbo generator stations. In addition to this the steam has been superheated to bring it to still higher temperatures. As long as the steam engine was used as the prime mover the increasing pressure and

temperature were quite gradual. The use of the higher temperatures as now adopted for steam turbine practice makes it practically impossible to maintain cylinder lubrication on an engine. In addition to this there are practical limitations in the ratio of expansion in the engine cylinder.

This, of course, is overcome to certain extent by the use of double or triple expansion engines. The uniflow engine is limited to one cylinder.

Steam at atmospheric pressure occupies 1700 times the volume of water and has a specific gravity of 0.0006. At a pressure of 3200 lbs. per square inch and under a temperature of 706° F. steam occupies the same volume as water and has a specific gravity of approximately one-third. With a given design of engine cylinder the ratio of expansion of the steam is fixed to a certain extent. If higher boiler pressures are used steam is taken by the engine over a portion of its stroke at this pressure and then expanded and finally exhausted. In an attempt to get a large ratio of expansion it is necessary to utilize a number of cylinders or considerable flywheel effect in order to equalize the effort of the engine.

During recent years when the steam turbine has been utilized more and more for the generation of power there has been a rather sudden change taking place in the use of higher pressures. Pressures around 1000 to 1500 pounds are being tried and in England we understand that a steam pressure of 3200 pounds per square inch is to be given a trial.

There is a limit to which we can go in total temperature, due to the fact that metals that are available for steam generating purposes undergo considerable loss of strength above 600° F. Considerable

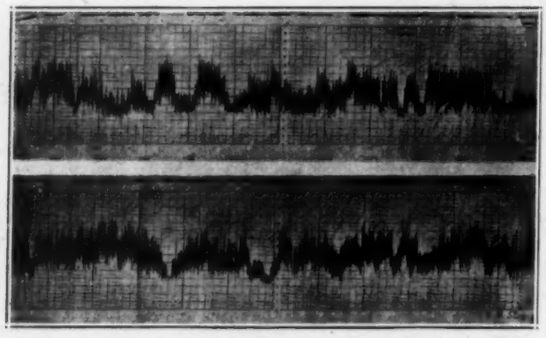


FIG. 3.

study is now being made to determine the strength of metals used for these higher temperatures and we believe there is no question but what this particular phase of the problem will be met.

We, of course, recognize steam engine practice should have made some progress, but its greatest advance has been made during the past years and the steam turbine is really taking up the situation where the steam engine seemed to have reached its limit. The extensive use of electric motors and steam turbines in the steel industry is only 15 or 20 years old, so that it can be stated that the electrification of this industry has not much more than made a start and the economies and advantages of this method of generation and utilization of power are not yet fully realized. While there may have been some argument as to whether electric drive had sufficient advantages ten or fifteen years ago to justify its use instead of steam drive, the situation today has changed so much that our basis of argument has entirely changed. The engineer who has installed electric motors instead of engines in the past has placed himself in a position to utilize the improved economy which may be obtained now and in the future in the generation of power.

There is an enormous growth in the adoption of electric drive. Practically every industry is being electrified. From Fig. 2 it will be seen that the Public Utilities of this country generated 45 per cent more power in 1924 than they did in 1919. Such an enormous growth in the adoption of electrification can only be based on substantial and fundamental reasons.

Some of the advantages of electrification are indicated by an examination of a graphic chart of the total load of a typical steel plant generating station. Fig. 3 is such a curve obtained at the Indiana Harbor Plant of the Youngstown Sheet & Tube Company. This 24-hour curve was taken in 1921, when tonnage outputs were low. A study of the chart will indicate there are times when the load is somewhat less than others and there are times when for a period the average is exceeded. The periods of low power demand indicates times when one or two of the mills are not in operation. However, the turbine plant and its boiler plant were operating at a fairly steady load during the entire 24 hour period. If this plant had had individual boiler plants or boiler plant for groups of engines, an interruption of a blooming mill with a sheet bar mill would mean quite a variation to that boiler plant and the same economy would not be obtained as is obtained where one boiler plant can serve the entire load of the plant.

If electric motors were used to drive this mill, and if they were supplied with power from a modern turbine plant the steam required per ton during a short test, such as described by Mr. Conway, would be approximately 200 pounds instead of 317 pounds as reported by the half-hour test on the uniflow engine.

Mr. Fennell, I believe, mentioned that he felt the uniflow engine should be used on big mills. In this case the engine was purchased to roll 100 net tons an hour. If this mill were electrified, the main unit would not take an average load equal to the capacity of the 2-1000 K.W. engine driven generators purchased to supply the auxiliaries of the mill. This illustrates very well the fact that we look upon a reversing blooming mill engine as a large consumer of steam, while the electric drive is quite moderate in its demand for generating capacity.

I often tell a story of an experience of Mr. Bebb, until recently Chairman of the Central Steel Company. This company purchased a 34-inch blooming mill in 1912, I think, and they were required to decide whether they should install a steam engine or an electric motor. Mr. Bebb, with some of his engineers, visited the Steel Company of Canada's plant where there is a 34-inch mill driven by an electric motor. At the time they walked into the motor room the mill was just being shut down. Mr. Bebb, who was a banker and not an engineer, walked up

to the switchboard attendant and asked him what had happened. He explained that they had been rolling for about an hour and were shutting down waiting for hot steel. He noticed him writing and he said to him, "What have you in this book?"

The man replied, "I was just putting down the kilowatt hours used in the last hour."

He asked him how much he used on the blooming mill and the man told him. They went out in the mill and he got the number of tons rolled during this period and he figured out, on the back of an envelope, how many kilowatt hours per ton were required, and then using the rate that he expected to pay for his power at Massillon, he soon knew, without any engineering, just what the power cost of rolling steel on his mill would be.

If we understand Mr. Conway's data correctly he has only measured the steam to the main unit and has not included the energy required on the auxiliaries such as those used on the condenser. Tests made where economies are based on the indicator cards or steam flow meters cannot be given the same credit as those tests where the water is weighed to boilers set aside for the individual unit under test, or where the condensate is weighed. We know in general some engineers do not accept results obtained through steam flow meters, although in this meeting there has been given considerable explanation why they should be able to give accurate results on this particular engine. If steam flow meters could be depended upon for this reversing engine where the demands for steam vary from zero to an extreme overload in the matter of seconds, we see no particular reason why they should not be acceptable on steam turbine tests where the turbine is set to carry constant load and there is only the slightest variation in the flow of steam to the turbine over a period of two or three hours. We, of course, all know that the steam flow meters are not acceptable on turbine tests. The following is taken from the Westinghouse General Requirements for contract demonstration economy tests:

(1) Each load test should be for two hours' duration, having been fixed and carried for approximately one hour preceding the starting of the test and held steady and uniform throughout the entire test period.

(2) Steam consumption is to be measured by collecting all of the condensate during the test period in suitable tanks and preferably weighing on accurate calibrated platform scales, or by volumetric measurement, that is carefully and accurately weighing the water required to fill each tank to a fixed overflow and then during the test make record of the number of fillings of each tank. The measurement requires that each tank as filled during test, contains the same amount of water as during calibration.

(3) The use of meters in the turbine steam line or condenser condensate pump discharge are not accurate or reliable and will not be acceptable.

The above extracts taken from our method of conducting turbine tests are given to indicate that the method of test as used on this engine is not comparable to that acceptable on steam turbine practice, even though the conditions for obtaining accurate readings are ideal as compared to those obtained on a reversing blooming mill engine.

It would not be possible, of course, to test a reversing mill engine at a constant load. This condition is maintained on a turbine in order to definitely establish the water rate at some particular load.

On page 51 of the 1920 issue of the Association of Iron & Steel Electrical Engineers, a summary of a test by Mr. Eppelscheimer is given where he segregated boilers and weighed the water to the boilers over a period of 17 hours. This is about the only definite way to establish the requirements of such a drive. Most of the K.W. hour consumption data on electric driven mills are those obtained for periods of from one day to a month, or a yearly figure. Many of the steam engine tests are based on tests lasting 30 minutes, or very often based on cards obtained when rolling one ingot. Monthly figures, of course, include the standby losses during idle periods, while the steam engine tests are made for very short periods, so that a comparison of the values published are not comparable. The engine tested by Mr. Eppelscheimer is a simple non-condensing engine when rolling steel to an elongation of 12.8, which is in excess of that rolled during a test made by Mr. Conway. Mr. Eppelscheimer finds that this simple engine required 1520 pounds per ton. With a condensing engine, such as described by Mr. Conway we would expect a material reduction in economy, but hardly in the neighborhood of one-fifth of that obtained by Mr. Eppelscheimer.

In 1921 a test was made on a simple condensing engine driving a 34" blooming mill. In this instance we also segregated boilers and weighed water to the boilers for a period of four days. When the mill was running at its normal rate the boilers required approximately 51000 pounds of water per hour. At that time the mill was only running four hours per day and during the remaining 20 hours when the mill was not in operation, the boilers required an average of 17000 pounds of water. In other words, during the idle period they took about one-third as much as when the mill was in operation.

In conclusion it seems a little unusual to question the installation of electrical apparatus for rolling mill drives at this time when in a number of instances the extension of gas engine generating plants has been made by the use of steam turbines rather than the additional gas engine units. The steam turbine can utilize higher initial temperatures and pressures and expand the steam to a greater vacuum than is possible with the steam engine. This development, which carries the steam practice beyond that which is possible for reciprocating engines, is responsible for the almost universal adoption of electrification. The decision which the operating engineers of our steel plants have made in regard to this question is indicated by a reference to the January Issue, 1926, of the Iron & Steel Engineer that have been enrolled in recent issues. In some instances the motors replaced engines, the mill being retained, while in some plants the modernization program included the replacement of the mills as well as the drives.

S. S. Wales: Mr. Stoltz's remarks give us another viewpoint, and I would like to ask him re-

garding the data on the increased efficiency of generating he referred to. We need that information and we also need articles for the Engineer. It would be very encouraging to us if we could look forward to having an article showing the charts which Mr. Stoltz unfortunately did not have with him in the way of slides.

G. E. Stoltz: I will be very glad to put this data in with the discussion.

S. S. Wales: I think that would make it very complete. Thank you.

Mr. Fennell stated that the Nordberg Company, having decided to adopt the uniflow engine, had to look around for a customer who had nerve enough and willingness to try the experiment. After reaching that point, the experiment had to be tried by some one and we are very glad that Mr. Stoop was willing to take the responsibility. I would like to call on Mr. W. J. Stoop, if he is here, to give us a few words on the subject.

W. J. Stoop*: Mr. Conway has presented the facts in a very able manner, but has said nothing as to the investment cost of the Nordberg Uniflow Engine compared with the Electric Drive. We made up a tabulated statement comparing the cost, and there was something like three-quarters of a million dollars difference in favor of the Uniflow Engine Unit.

S. S. Wales: I am sorry Mr. Stoop cannot give us any more on this subject, but I want to congratulate him again on his willingness to take hold of the problem and on the fact that he has made such a good showing with it.

We will throw the meeting open for general discussion, but I am afraid Mr. Conway will have to write another paper to answer all the questions he has before him already, so we will ask you gentlemen who want to talk to be prompt in coming forward with your discussion.

There do not seem to be any more candidates to discuss this paper, so we will ask Mr. Conway if he will reply to what has been brought up.

M. J. Conway†: Mr. Chairman, I think I stated when I started that this was a controversial subject. It apparently is.

Stating the Wheeling Steel Corporation's position in the matter, the data presented here today was given in response to a request from the Association. Everyone wanted to know what the Nordberg Engines were doing. The company has not presented this paper for the purpose of showing that a steam engine is the best drive for a blooming mill, or that it is not. We have presented these data from an unbiased standpoint because you wished these data to be presented, and can be used as reference work as suggested by Mr. Petty, if necessary.

Replying to Mr. Wales and others on the cost of repairs and maintenance, I believe that the engines have not been running long enough to make a fair comparison, if figures could be compiled covering ten years' operation then we would have something useful to submit and make comparable with other types of drives.

The chief trend of all the questions was "What does it cost in dollars and cents?" That is a fair question to ask.

Mr. Schnure stated that at their Sparrows Point plant they were rolling steel for 17 to 18 K.W. per ton. Comparing this with our steam driven mill as using 400 lbs. of steam per ton and steam at 22 cents per 1000 lbs. the cost on the steam unit would be 8.8 cents per ton, and at Sparrows Point using 17 to 18 K.W. per ton with power at half a cent per K.W. the cost would be 8.5 to 9.0 cents per ton, so that there is very little difference in the cost performance of the two drives.

Replying to Mr. Stoltz, of the Westinghouse Company, using his comparison of the most modern electric drive performing the same work as is being done at Steubenville for 14 K.W. Assuming again K.W. at a cost of half cent the cost would be 7 cents per ton, using 317 pounds of steam at 22 cents per 1000 lbs. the steam cost per ton is also 7 cents per ton, so there is very little difference.

I believe the deciding factor is the relative cost of steam and power in the location where the drive is to be installed. No doubt the electric drive is a great competitor of the steam engine where power is cheaper, there is no question about that, none at all.

Replyng to Mr. D. M. Petty and others I do not see why a steam drive should be dirtier than an electric drive as the deposition of mill dust in both cases is substantially the same, and keeping the drive clean is merely a matter of so much labor, and with forced feed lubrication throughout there is very little oil spillage around the Nordberg engine. In the steam drive it is true that we have steam lines in addition, but if properly installed these should not cause any more dirt to accumulate than the transmission lines with an electric drive.

Both Mr. Wales and Mr. Petty stated that the economy of the steam engine could not be as easily recorded and watched as the electric drive. With the uniflow engine it is possible to set up a meter installation that can be relied upon to record the engine performance, and if necessary the engine can be indicated as an additional check on its performance.

Replying to Mr. Umansky, the steam consumption is given per net ton of material rolled because the engine builder's estimate was expressed in pounds of steam per net ton of material rolled and these data given here today were taken from tests made to determine if the engine was performing as the builders said it would. Personally I believe the fairest method of comparing mill performance is to use the unit of net or gross ton of material rolled at a certain standard of elongation instead of per ton of mill product because of the difference in yield between the various mills.

Mr. Umansky's tabulation is very interesting, but let me remind him that the steam pressure and superheat used on this engine are very much higher than those he has recorded and he has evidently forgotten that we have another record in the Association Files (see Proceedings A. I & S. E. E., 1924,

*Chief Engr., Wheeling Steel Corp., Wheeling, W. Va.
†Comb. Engr., Wheeling Steel Corp., Steubenville, Ohio.

Page 568). Mr. Frank McGough gives the figures in a discussion of Mr. C. H. Hunt's paper of 450 to 575 lbs. of steam per ton of ingots rolled by the twin tandem compound engine of the Weirton Steel Company.

Mr. Umansky notes that I justify the accuracy of the flow meter by the fact that the engine consists of four double acting cylinders which creates almost a constant demand. I also stated that we have a large receiver at the engine.

Mr. Fennel has stated that these receivers hold five times a much steam as the engine requires in one revolution.

Mr. Umansky's Company also manufactures steam flow meters which operate on the same principle as the Republic Flow Meter and will install them to measure steam to reciprocating engines and pumps which are equipped with very large receivers, (see G. E. Bulletin 46501-E).

Replying further to Mr. Stoltz and Mr. Umansky, regarding the metering of steam. We were unable to isolate any boilers in this particular test, but we have meters measuring steam to the other units receiving steam from the same boiler house and by comparing the totals we find that they continually check very closely with the boiler meters which in turn check with the feedwater meter. The steam consumption shown as used by the engine includes the steam used at the air pump.

The one point lost sight of is the difference in installation cost which was stated here to be three-quarters of a million dollars in favor of the uniflow engine unit.

The total cost of steam charged per month to the engine and air pump does not amount to as much as the fixed charges would be on the difference in investment.

Let me state again that the information given at this meeting was given by the Wheeling Steel Corporation at the request of the Association to satisfy the many inquiries regarding the performance of these engines and was not intended to be a discussion on "Steam versus Electric Drive."

S. S. Wales: Gentlemen, I think that we have had a very profitable meeting this morning and I wish again in the name of the Association to thank Mr. Conway and his company for this paper. Mr. Conway has done a great deal of very valuable work on a subject that we all should know about, and he has been able to present it through the courtesy of his company, which this Association greatly appreciates.

If there is nothing further to come before us at this time, the meeting will stand adjourned.

Does Accident Prevention and Safety Work Pay?

The United States Steel Corporation has answered this question in their bulletin number 11, which is a review of twenty-five years' work in Safety, Sanitation and Welfare.

When Judge Gary, in 1906, in behalf of the finance committee of the Steel Corporation, promised that no reasonable request for funds to insure greater safety for the men in the mills and mines or to better their conditions, would be refused, he wrote into every employee's life in the steel industry, an opportunity to enjoy the pursuit of life, health and happiness without hazard. This is a broad statement, but yet it is true. It required particularly at that time in 1906, a forceful character, a leader, to place his absolute approval upon the work of safety.

The fact that Judge Gary, backed by the United States Steel Corporation, was ready and willing to accept the responsibility in one of the most humanitarian moves that has ever been instituted in industry made the work of accident prevention and safety work a possibility. It was not long after that until the entire steel industry in America gave the safety movement its financial and moral support.

What has been accomplished in the twenty-five years in the Steel Corporation? In 1925 the number of serious accidents per 100 men employed was 60.22 per cent less than in 1906 when these activities were started, and disabling accidents were 80.07 per cent less than in 1912. This means when stated in round figures that 46,863 men have been saved from serious injury and 322,408 men have been saved from any injury which resulted in loss of time.

Your attention is invited to an analysis that has been made by Mr. Charles L. Close, Manager of the Bureau of Safety, Sanitation and Welfare, covering the classification of causes of accidents in which 306,421 accidents have been classified as to cause, also to a graphic table which was prepared showing the per cent decrease in serious accident rate under 1906 and the per cent decrease in disabling accident rate under 1912

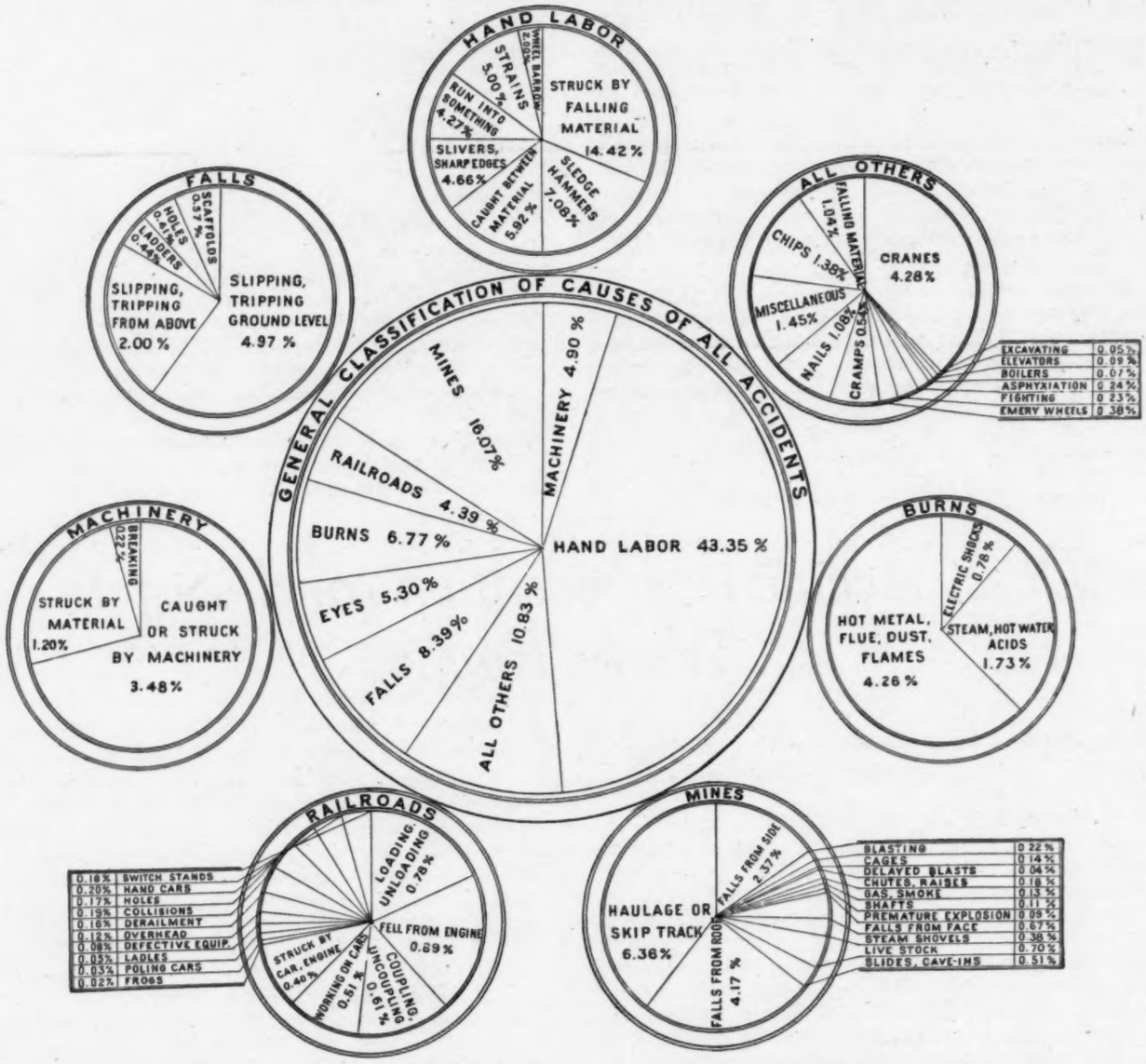
Quoting James J. Davis, Secretary, Department of Labor, Washington, D. C., in a letter to Judge Elbert H. Gary:

"Accident statistics for the iron and steel industry have been kept in the Bureau of Labor Statistics of this Department going back to 1907, during which time the Commissioner of Labor Statistics informs me frequency accident rates in the industry have dropped from 80.8 per million one man hour exposure in 1907 to 30.8 in 1924, and that the severity rates have dropped from 7.2 to 3.

"More satisfactory still than this is the achievement of a smaller group of plants composed largely of the United States Steel Corporation's subsidiaries and in which more energetic and systematic methods have been installed and tenaciously adhered to. In this group of plants the frequency ratio has dropped from 60 3 per million hours of exposure in 1913 to 10.2 in 1924, and this group contains nearly one-half

CLASSIFICATION OF CAUSES OF ACCIDENTS

306,421 Accidents Classified as to Cause



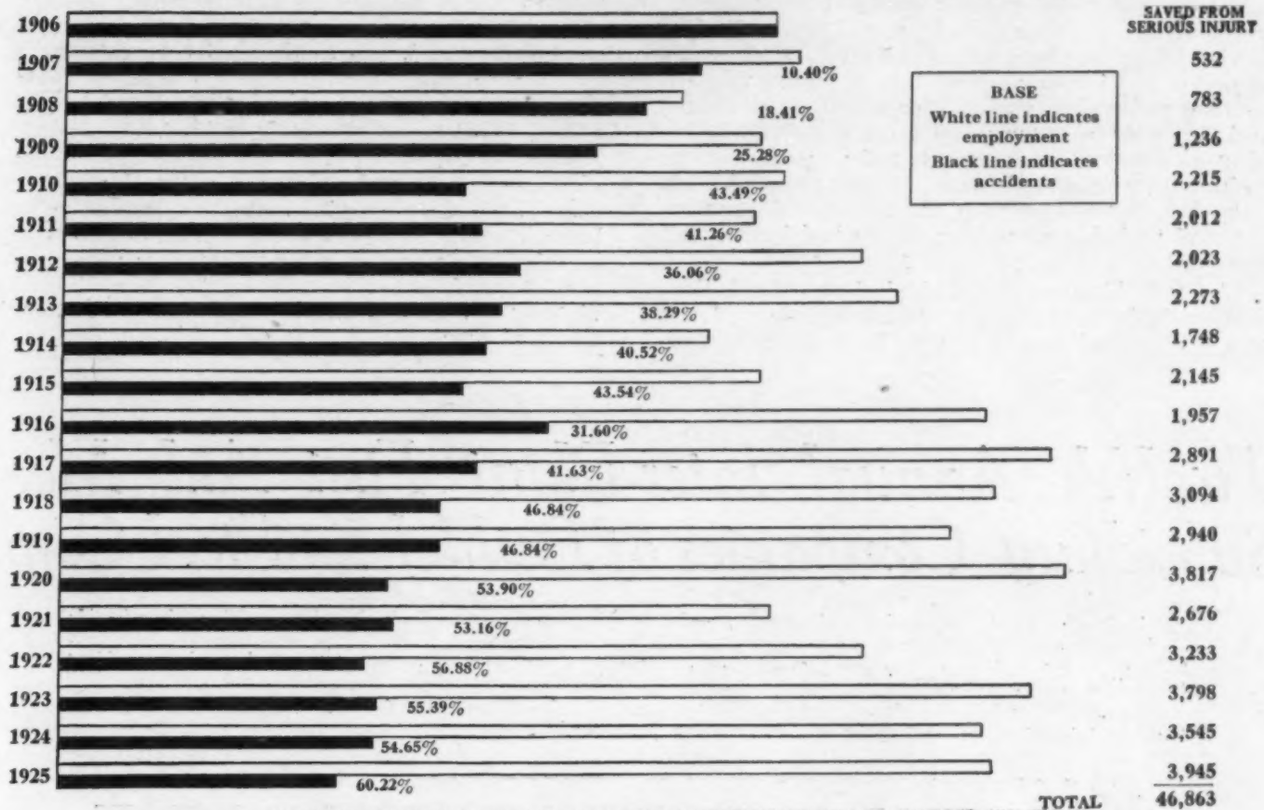
THIS chart shows the causes of 306,421 accidents which have occurred in the plants, mines and other operations of the United States Steel Corporation over a long period of time. But 4.26% of the accidents were due to hot metal, flue dust or flames, which might be considered entirely distinctive to the steel industry and not to other industries. Only 4.90% of the accidents were due to machinery causes, while hand labor was responsible for 43.35% or nearly one-half of the accidents, the majority of which cannot be controlled by the use of mechanical safety devices and appliances.

BUREAU OF SAFETY, SANITATION AND WELFARE

CHARLES L. CLOSE, *Manager*

APRIL 1, 1926

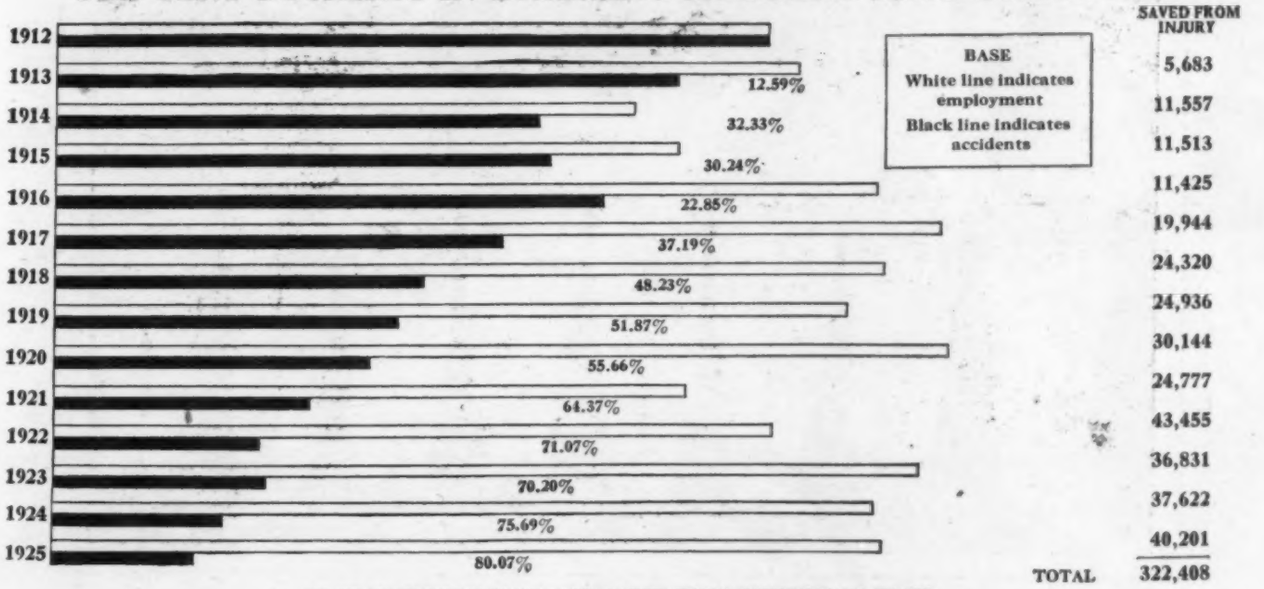
PER CENT DECREASE IN SERIOUS ACCIDENT RATE UNDER 1906



	SAVED FROM SERIOUS INJURY
1906	532
1907	783
1908	1,236
1909	2,215
1910	2,012
1911	2,023
1912	2,273
1913	1,748
1914	2,145
1915	1,957
1916	2,891
1917	3,094
1918	2,940
1919	3,817
1920	2,676
1921	3,233
1922	3,798
1923	3,545
1924	3,945
TOTAL	46,863

46,863 EMPLOYEES HAVE BEEN SAVED FROM SERIOUS INJURY IN 19 YEARS

PER CENT DECREASE IN DISABLING ACCIDENT RATE UNDER 1912



	SAVED FROM INJURY
1912	5,683
1913	11,557
1914	11,513
1915	11,425
1916	19,944
1917	24,320
1918	24,936
1919	30,144
1920	24,777
1921	43,455
1922	36,831
1923	37,622
1924	40,201
TOTAL	322,408

322,408 EMPLOYEES HAVE BEEN SAVED FROM INJURY IN 13 YEARS

The black lines show graphically the accident rate per 100 employees for each year while the figures opposite show the per cent decrease and the number of men saved from injury. The white lines indicate employment in the corresponding years. It will be noted that since 1906, which year marked the beginning of our intensive safety activities, serious and fatal accidents in the operations of all the subsidiary companies of the United States Steel Corporation have been reduced 60.22 per cent, and 46,863 men have been saved from serious or fatal injury; and since 1912 disabling accidents have been reduced 80.07 per cent, which means that a total of 322,408 accidents were prevented and this number of men were saved from any injury which resulted in a loss of time. A disabling accident statement classifying the severity of accidents was adopted in 1912. Prior to this date accidents were classed as either serious or minor, the latter including all accidents considered of a minor character regardless of whether time was lost or not. Disabling accidents are all accidents which cause a loss of time greater than the balance of the working turn.

of the iron and steel industries in the United States.

"What especially pleases me is your reported statement that the United States Steel Corporation has found that accident prevention and safety work really pays from a dollar-and-cents point of view. You are reported as having stated that the United States Steel Corporation in ten years spent $9,763,063 in accident prevention work and that the money saving resulting therefrom had been $14,609,920 in addition to the fact that 250,000 men had been saved from injury, and probably more than 40,000 had been saved from fatal injury.

"As a self-insurer the United States Steel Corporation is in a position to know whether or not there is an actual money gain to be derived from intelligent accident prevention work, and this statement of the Corporation's experience will be of inestimable value to me in reaching that percentage of employers with whom the humanity appeal does not get one very far, and to whom you must show a chance to save money or they will not go along."

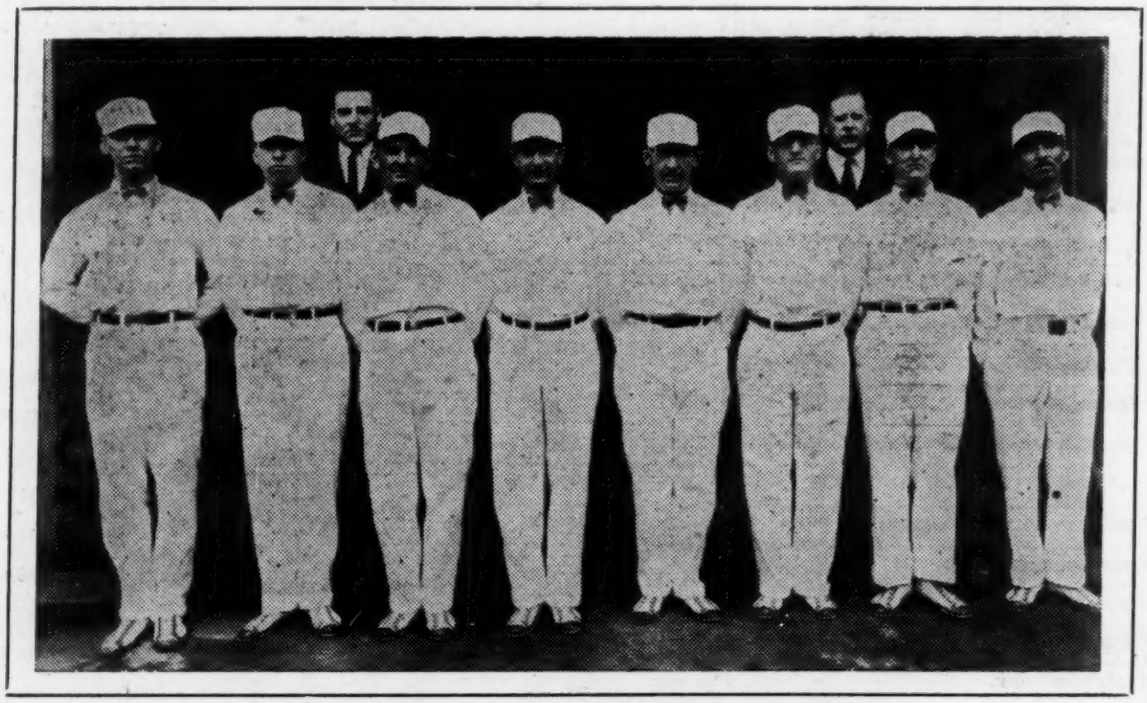
The Association of Iron and Steel Electrical Engineers, founders of the first organized national movement in America for the prevention of accidents and safety work, wishes to extend to the United States Steel Corporation their sincerest congratulations in preventing in twenty-five years a possible 40,000 fatal accidents and a possible elimination of 300,000 accidents, which would have resulted in a loss of time.

Twelfth Annual Inter-Plant First Aid Meet Subsidiary Companies of Bethlehem Steel Corp.

Bethlehem Steel Corporation endeavors to make working conditions safe in its plants. Through scientific study most accidents formerly accepted as inevitable are now prevented. By even greater thoughtfulness and caution on the part of all employees such accidents as now occur can be largely eliminated. Thus, accident prevention in Bethlehem plants becomes a matter of vigilance and education.

In addition to bringing about proficiency in the care of injured workers, first aid instructions help maintain the interest of all employees in safe working practices.

E. G. Grace.



Rosedale Coke Works First Aid Team Wins Steel Works Tourney

Reading from left to right, they are—First row: T. S. D. Ninde, Captain; Richard Stevens, Joseph Stem, J. M. Robertson, Clarence Allison, Burton Tingue, Thomas Callister, and Frank G. Buechley, patient. In background—Willard W. Brant, First Aid Instructor of local works and John A. Northwood, Superintendent of Safety.

Above is a photo of the championship first aid team of the Bethlehem Steel Corporation, composed of men from the Rosedale Coke Works of the Cambria plant. This aggregation placed first in the twelfth annual first aid meet at Bethlehem, surpassing representative teams from all mill divisions of the corporation in the excellence of their first aid work.

TABLE OF DISCOUNTS FOR FIRST AID STEEL PLANTS

1. Not Doing Most Important Thing First:	
(a) Failure to temporarily control hemorrhage previous to application of tourniquet	7
(b) Failure to remove patient to place of safety at proper time	4
(c) Failure to do the most important thing first other than (a) and (b)	6
2. Hemorrhage:	
(a) Tourniquet improperly applied so as not to stop bleeding	10
(b) Tourniquet not applied (10 plus 2)	2
(c) Tourniquet applied so as to stop bleeding but at wrong points, or in such a way as to injure patient	4
3. Shock:	
(a) Not treating shocks	6
4. Artificial Respiration:	
(a) Improper or inefficient preparation of patient	3
(b) Incorrect timing of pressure	2
(c) Ineffective method	9
5. Bandages and Dressings:	
(a) Failure to entirely cover the wound	2
(b) Bandaging or treating wrong location of injury	4
(c) Bandage too tight	2
(d) Bandage too lose	2
(e) Bandage improperly applied	2
(f) Insecure or granny knot	1
(g) Unclean bandages or dressings	2
6. Splints:	
(a) Wrong splint	2
(b) Improperly padded	2
(c) Improperly applied	2
(d) Failure to use splint	2
7. Slow Work:	
(a) Slowness in work (Deduct 1 point for each minute over allotted Time)	1
(b) Lack of neatness	1
(c) Lack of attention	2
8. Failure To Be Aseptic	6
9. (a) Awkward Handling of Patient	4
(b) Assistance Lent By Patient	2
10. Failure to have on Hand Sufficient and Proper Material to Complete Dressings	3
11. Failure to Command Properly	1
12. Improper Treatment Not Covered by Above	4
	100

The Silver Trophy here pictured will be held for one year by the Plant or Division whose team wins the First Aid Competition. There are two of these Trophies—one being competed for by the Steel Plant teams and the other by the teams from the Mines

The Steel Plant Trophy was won last year by the Bethlehem Plant, while the Trophy for the Mine Divisions was won by the Ellsworth Division. This year, the Steel Plant Trophy was won by the Rosedale Coke Works team, Cambria Plant.

In addition to these Trophies, Cash Prizes are awarded to the individual members of the winning teams.

Safe Crane Operators Physical and Mental Requirements

By CHARLES M. SWINDLER, M. D.*

WHEN we consider that in the daily operation of a crane, the safety of much valuable property and many lives are repeatedly entrusted to the skill, judgment and physical welfare of a single man, the necessity for a regular inspection and check-up of the physical and mental conditions of this man, is perfectly obvious. Indeed, the laws of most of the States recognize this necessity; our own State of Pennsylvania requires that "no person shall be permitted to operate a crane whose hearing or eyesight is defective, or who may be suffering from heart disease or similar ailments. A physical examination is required at least once each year."

*Carnegie Steel Co., Clairton Works, Clairton, Pa.

In the various plants of the Carnegie Steel Company, the physical examination of a craneman (and trainmen) begins with the routine physical examination of all employees:

(a) When they first go to work.

(b) When they go to work on a new job in a different department.

(c) As often as shall be deemed necessary in certain special cases, such as symptoms of chronic diseases, etc.

This routine physical examination was first instituted in the Carnegie plants by Dr. Wm. O'Neill Sherman, Chief Surgeon, some fifteen years ago, when the idea, though already in practice by the

railroads for many years, was regarded as something of a novelty by industrial concerns, and looked askance by organized labor, ever suspicious and ready to see some ulterior motive on the part of the employer in anything new required of the employee.

It was then realized that such an examination to be of value should be:

(a) Conducted by a qualified and experienced physician.

(b) Should be done with dispatch and in a decent manner, without offense to the sensibilities of the applicant and with due regard for the principles of hygiene.

(c) Should be sufficiently detailed to be thorough, yet not so much so as to become unwieldly or impractical.

The routine of examination, briefly, is:

The applicant presents to the examining physician a card from the employment office, upon which is recorded the name, age, social status, etc., of the applicant, and the job on which he is expected to work. This information is verified by interrogation of the applicant by the physician in cases of suspected discrepancy.

The vision and hearing are then checked, usually by the assistant; the first with the aid of a Snellen test card under standard conditions; the latter, by spoken voice and then by the click of an instrument called an acoumeter. The click of the stem of a watch may be substituted for an acoumeter.

The applicant is then sent into a clean, hygienic booth, where he may remove his clothes in private, and remains there until called for, when he is taken into an adjoining room, or curtained off space and examined in private by the physician. The examination is thorough, beginning first, with a general inspection, and then starting at the top of the head, taking in turn consideration of the eyes, ears, nose, teeth, neck, body, spine and extremities, scrutinizing each part carefully and using the usual methods of physical examination recognized among physicians, for any deviations from the normal.

These findings are recorded on the physician's own card record and kept under lock and key by him in order that no privilege or professional information may be divulged and get into unauthorized hands. The findings, as a result of this examination, are properly evaluated and the applicant for employment is classified:

"A" the perfect man (very seldom seen);
"B" the acceptable man;
"C" the man who has some disability, but can safely perform certain classes of work suited to him;
"D" the man who is absolutely unacceptable and is rejected for employment.

Special Examination

In the selection of cranemen, there are certain considerations supplementing the above routine. Cranemen are limited strictly to the first two classes, A and B.

The physician, personally, checks the vision and hearing, and in addition to the ordinary Snellen card test, a color test is required. This last is made by the aid of a lantern that has glass diaphragms of different standard colors which are successively presented for the applicant's observation at a standard distance. This test may also be supplemented by the matching of colored woolens.

A vision of at least 20/40 in each eye is uniformly required to be acceptable as a craneman. If the vision is less than 20/40, can be satisfactorily corrected by glasses, and the oculist finds no constitutional diseased condition of the eye, the applicant may yet be acceptable.

The hearing should be at least 20/15 as represented by the acoumeter, but this requirement is also supplemented by what is regarded by the physician as the necessary ability to hear easily and quickly, and interpret accurately the spoken voice.

The man should have sense and use of all of his members so as not to interfere with his handling of control levers in any manner.

Any evidence of heart disease or epilepsy absolutely disqualifies a man as a craneman. These are, in the main, the physical qualifications for cranemen.

When it comes to mental qualifications, psychology has not yet become an exact science and we have no instruments of precision which are practical by which we can satisfactorily measure a man's mental attainments. It is true a great variety of formal mentality tests have been advocated from time to time, with a view to establishing some standardized unit of measurement, but to date, most if not all of these systems have been too complicated, unwieldly and time-consuming; nor do they accurately reflect working conditions sufficiently well to have been permanently adopted, so far as the writer knows, by any large unit of industry. An examining physician of good, practical judgment can formulate a very close, accurate estimate of a man's mentality by the precision, quickness and correctness with which the applicant responds to the questions and routine manipulations necessary for a physical examination; especially if the physician is previously informed as to what position the applicant expects to fill, and is, therefore, rather more on the alert than usual. So far the best idea of a man's mental capacity for the job of craneman is gained by close observation of his reactions under the acid test of experience in the cab, safeguarded by the control and direction of an older and experienced craneman.

In training new men for cranemen, probably it is more advantageous to select men from the first two decades of life, when the powers of co-ordination are still plastic and easily trained, but not so early in years that the judgment is still immature. After a man has passed the middle period of life, his ideas, reaction and co-ordination become somewhat fixed. He can still satisfactorily perform a series of co-ordinating movements which he has already learned, but it is generally very difficult for him to learn a new set of movements such as might be entailed in the handling of an entirely different piece of apparatus than that to which he is accustomed. With advancing years when senile and degenerative changes begin to appear, these men should be checked very closely by routine physical re-examination, and in addition, urinalysis and blood pressure observation be made.

The State requires re-examination each year. With the older men, say past 45, it is the opinion of of the speaker, this could well be done with profit every six months or oftener.

Strength of Gear Teeth

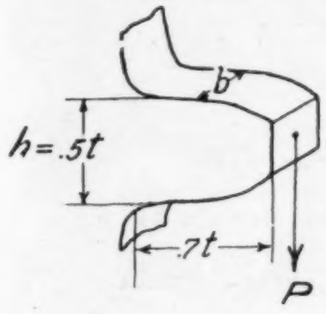
Stresses due to load and shock

By E. KIEFT*

A. SPUR GEARS

The strength of the gear teeth is found by means of formula (generally known as the cantilever formula)

FIG. I



$P = \frac{bt}{16.8} S$, in which (1)

P = the working load or tooth pressure in lbs

b = width of tooth in inches = 2 to 5 t

t = circular pitch = $\frac{2\pi R}{\text{No. of teeth}}$

R = radius of pitch circle in inches

S = stress in lbs per square in., which varies with the speed, (the table values are for cast steel, use .4 S for cast iron) the factor 16.8 follows from the relation — force x lever arm = section modulus x stress

or $P \times .7t = \frac{bx(.5t)^2}{6} S = \frac{bt^2}{24} S = \frac{bh^2}{6} S$

therefore $16.8\ P = \frac{St^2}{t} = bt S$ and $P = \frac{bt}{16.8} S$

Speed C	S
100-150	20000
150-250	16000
250-400	12000
400-700	10000
700-1000	9000
1000-1300	8000
1300-1600	7000
1600-2000	6000
2000-2500	5000

$h = .5t$ = thickness of tooth (minimum)

.65 to .7t = height of tooth

The above formulas always give safe results for any kind of gear used in mechanical engineering. The Lewis' formulas give much higher results for P but do not allow for wear and are therefore not suitable for heavy duty. The substitution $h = .5t$ gives a margin against impact

The horse power transmitted becomes then $HP = \frac{PC}{33000}$ (2)

in which C = speed at pitchline in feet per minute

$C = 2\pi R n$ when R in ft.

n = revolutions per minute

The formulas (1) and (2) hold also for helical gears, in this case b is equal to the width of the worm wheel at the pitch circle.

*Engr., Illinois Steel Co., Chicago, Ill.

The Lewis formula gives for spur gears

$P = y\ b\ t\ S$ in which y is a factor correcting the effect of shape and number of teeth, P, b,t and S are the same as above. The horse power formula is identical with (2).

$Y = 0.154 - \frac{0.912}{z}$ for involute teeth 20° obliquity

$y = 0.124 - \frac{0.684}{z}$ for 15° involute and cycloidal teeth

z = number of teeth

This means that a gear containing 50 involute teeth of 20° obliquity would be more than twice as strong as indicated by formula (1) This is correct for new gears but not for worn gears. The Lewis formula is theoretically correct and should be used for machinery as used in Automobile engineering and other purposes, which warrant little wear by good lubrication and maintainance. Stresses due to load may decrease with the number of teeth, but not the stresses due to shock as will be shown in following discussions.

We find also in some mechanical engineering handbooks an imperical formula for herringbone gears. In one book we find $P = \frac{k\ b\ t}{2.5}$ (Machinery) and in another $P = .4\ k\ b\ t$ (Marks) in which k about equal y S at speeds below 1000 ft/min. This would mean that a spur gear can transmit about 150% more load or horsepower (when calculated by Lewis formulas) than a herringbone gear, which is contrary to the general contention that a herrringbone gear is at least 40% stronger than a spur gear of the same pitch and face.

B. BEVEL GEARS $P = \frac{bt}{16.8} S$ (1)

Use average circular pitch and average speed at pitchline; for most cases the maximum circular pitch and speed at pitchline is within the safety limits.

C. HERRINGBONE GEARS $P = \frac{bt}{12} S$ (1a) $b = 3$ to $10\,t$ (1b)

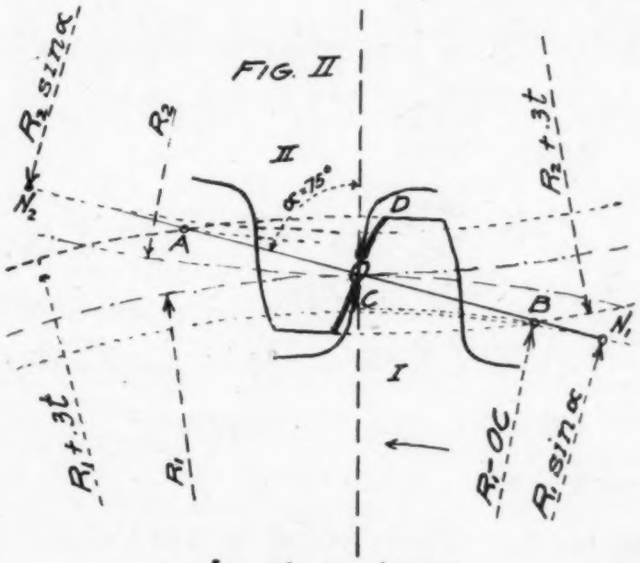
In this case add 40% to the results obtained for the same size of spur gears. The foregoing formulas allow for wear for there are generally nearly two or more teeth in contact when

T' = duration of contact = $\frac{\text{Length of line of contact}}{\text{Circular pitch}}$ is greater than two; the length of the line of contact is taken from the original log.

For involute teeth as used in mill work, the length of the line of contact is the length of the straight line A - B Fig. II.

For standard teeth we find approximately

$T' = m_1 \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$ in which m_1 varies from .4 to .5 dependent upon shape of the tooth



Circular pitch = $\frac{2\pi R_1}{n_1} = \frac{2\pi R_2}{n_2}$

R_1 & n_1 = radius & number of teeth gear I

R_2 & n_2 = radius & number of teeth gear II

for $n_1 = 30$ and $n_2 = 40$

We find $T' = 1.86$ for $m_1 = .45$. Doubling the number of teeth would give

$T' = .45 \sqrt{\frac{4800}{140}} = 2.62$

Involute teeth
angle of obliquity = $90° - \alpha = 15°$
CD = Wearing Surface ; No. of teeth ≥ 20

It is not possible for the tooth pressure P to act on the end of the tooth as long as T' is greater than 1.5 provided centers of the gears are

mounted and kept in place, that is at a distance = $R_1 + R_2$

The wear of the bearings causes the gears to move out of proper mesh and therefore a wearing of the teeth to knife edges is witnessed in practice. It is therefore that the requirements of strength are still computed on the cantilever basis with the assumption of only one tooth in action resisting all the pressure on the edge of the tooth, which produces the same stress as when the force P is acting on the corner or end of the outer edge of the tooth, provided the width of the tooth (b) is not over three times the pitch (t). It is, however, not the static stress produced by the load pressure P, which causes the tooth to break, but the forces due to impact, especially when the masses of the gears are large as compared with the weight of the tooth. For example

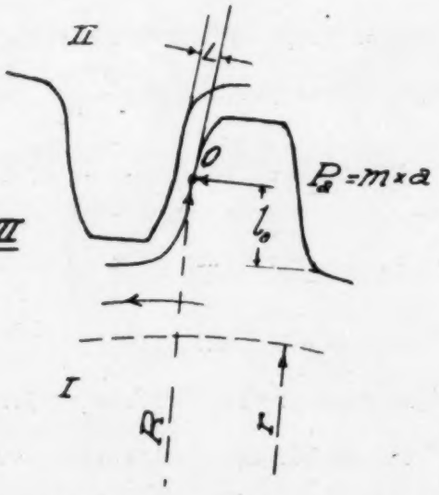


FIG III

Let there be a backlash of $\frac{1}{16}$ " = L

T = the time of acceleration = $\frac{1}{100}$ sec.

a = acceleration in ft. per sec.^{2}

For a short distance we may assume uniform acceleration

then $\frac{L}{12} = \frac{a}{2}T^2$ and $a = \frac{L}{6T^2} = 10000 \times \frac{1}{96}$

or $a = 104.17$ ft/sec.^{2}

$.5t = \frac{\text{thickness}}{\text{width}}$ of base of tooth (minimum)

t = circ. pitch in inches

R = distance center of gear (I) to center of impact (o) in ft.

r = radius of gyration of gear (I) in ft.

$$r = \sqrt{\frac{I_m}{M}} = \sqrt{\frac{32.2 \times \text{physical moment of inertia in lb-Ft. or ft. lbs.}}{\text{weight of gear in lbs}}}$$

I_m = physical moment of inertia in lb-Ft. ; $M = \frac{\text{weight of gear in lbs}}{32.2}$

32.2 = acceleration of gravity in ft./sec.^{2}

Force = Mass x acceleration = ma

m = mass of gear with reference to center of impact = $(\frac{r}{R})^2 M$

Let weight of gear with references to center of impact = 644 Lbs

then Force = $\frac{644}{32.2}$ x 104.17 = 2083.4 lbs = P_a

The impact energy is equal $\frac{m}{2}V^2 = \frac{m}{2}(a\ T)^2 = maL = P_a L$ inch Lbs

2083.4 x $\frac{1}{16}$ = 130.2 inch. lbs or 10.85 ft.lbs

This energy has to be taken up by the resilience of the gear teeth, which are subject to the blow of the impact. The energy due to impact produces stresses in the gear teeth combined with vibration, sound and heat losses. The stresses may become high when masses and acceleration are of considerable magnitude. The omission of vibration and heat losses gives us the maximum stress for each specific case. We have then: total impact energy, maL of the driver gear (I Fig. III) equal resilience of two gear teeth, that is one tooth of the driver gear absorbes the same amount of energy as one tooth of the driven gear, this is the maximum condition for it assumes no energy consumption due to acceleration of mass of the driven gear, which is approximately the case, when the latter is big as compared with the former; or when the latter is held by resistance.

The resilience of a cantilever is $\frac{P_1 f}{2}$, in which P_1 = maximum pressure due to impact; f = deflection of cantilever or gear tooth.

From Mechanics we have

$$f = \frac{P_1 l_o^3}{3EI} \text{ inches}$$

E = 30,000,000 (mod. of Elast.) lbs/sq.in.

I = geometrical moment of inertia of gear tooth $(\text{inch})^4$

= $\frac{bh^3}{12} = \frac{bt^3}{96}$ when thickness of tooth = $\frac{1}{2}$ pitch = $\frac{1}{2}t$ and width of tooth = b

let $l_o = \frac{1}{2}t$ = distance of center of impact from base of tooth in inches

The value of $l_o = \frac{1}{2}t$ represents the most severe conditions to be expected in practice, for it means that the gears are 20% of pitch out of mesh, which is equal to nearly 5/8" for a 3" circular pitch. $l_o = .4t$ when the gears are in proper mesh, that is, distance between the two centers equal $R_1 + R_2$ as shown in Fig. II.

We have then

$$maL = 2\frac{P_1 f}{2} = \frac{P_1 l^3}{3EI} = \frac{P_1^2 t^3 96}{24 E b t^3} = \frac{4P_1^2}{bE}$$

$$\text{and } P_1^2 = \frac{maLbE}{4} \text{ or } P_1 = \frac{1}{2}\sqrt{maLbE}$$

The elastic limit of the teeth is reached when $P_1 l_o$ increases as indicated by $P_1 l_o = \frac{b(.5t)^2}{6} S = \frac{bt^2 S}{24}$ and for $l_o = \frac{1}{2}t$ we find

$$P_1 = \frac{btS}{12} = \frac{1}{2}\sqrt{maLbE}$$

Hence

$$S = \frac{12P_1}{bt} = \frac{6}{bt}\sqrt{maLBE} \text{ lbs/sq.in.} \qquad (3)$$

Substitution of $a = \frac{L}{6T^2}$ gives

$$S = \frac{L}{btT}\sqrt{6mbE} = \frac{2.45L}{\sqrt{b}tT}\sqrt{mE} \text{ lbs/sq.in.} \qquad (4)$$

$$\text{and } T = \frac{L}{btS}\sqrt{6mbE} \text{ (time in seconds)} \qquad (5)$$

Formula (4) shows that the stress due to impact decreases when the product of face (b) times pitch (t) times Time (T) increases or the stress varies inversely with the $\sqrt{b} \times t \times T$, therefore large pitch appears of more importance than large face. On the other hand, large pitch reduces the number of teeth and duration of contact, which makes it necessary to consider both cases especially, when smooth running is required as a prime factor. In many cases the strength and uniformity of wear of involute gear teeth is improved upon by making the height above the pitch circle more than .3t in case of the smaller gear without reducing the standard height (.7t). Variation of height above pitchcircle affect the line of contact A - B Fig. II. Uniform wear is to be expected (according to K. Buchner) when $AO/OB = n_2/n_1$, Fig. II. Minimum wear and maximum efficiency is, however only obtainable by means of proper LUBRICATION and MAINTENANCE of distance of gear centers equal $(R_1 + R_2)$.

and less than .3t in case of the larger gear,

The impact stresses produced in the gear teeth Fig III during starting and stopping or reversing of the engine or motor connected with the gear drive are calculated by means of formula (3), in this case the acceleration

$$a = RK = R \frac{\text{Starting torque of engine or motor in ft. lbs.}}{\text{Combined moment of inertia of rotating parts in ft.lbs}}$$

K = the angular acceleration of point O (Fig. III)

R = distance center gear to point O in feet

The following is an illustration of the application of formula (3)

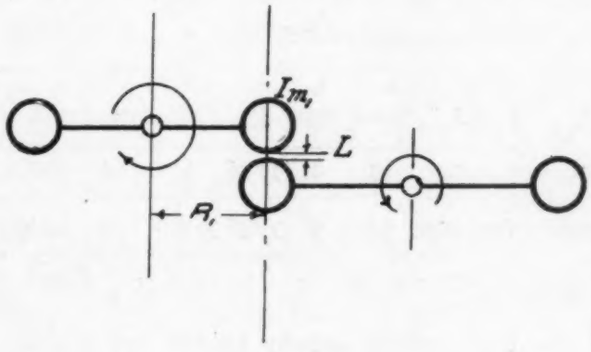


FIG. IV.

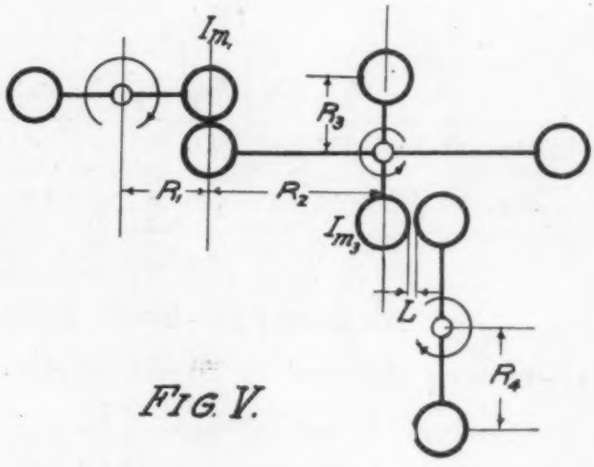


FIG. V.

Let T_t = starting torque of motor or engine in ft.lbs.

I_1 = combined moment of inertia in ft.lbs of motor armature, main shaft, fly wheel and other rotating parting connected with the main shaft. In case of a steam or gas engine we have also to include the inertia of the reciprocating parts.

I_2 = combined moment of inertia in ft.lbs of rotating parts connected with second shaft.

I_3 = ditto for third shaft.

The inertia of the moving parts determines the angular acceleration. The linear acceleration of the point of impact becomes then

$a = R_1 K = R_1 \frac{M_t}{I_1}$ for the case shown in Fig. IV

$a = R_3 K = R_3 \frac{M_t}{I_1 + I_2 \frac{R_1}{R_2}} = \frac{R_2 R_3 M_t}{I_1 R_2 + I_2 R_1}$ for the case Fig. V

The reduced mass "m" is determined from the relation

$mR_1^2 = Im_1 =$ mom. of inertia driver gear Fig. IV *in ft.lbs.*

$mR_3^2 = Im_3 =$ " " " " " Fig. V " *ft.lbs.*

R_1, R_2, R_3, and R_4 in feet; backlash L in inches, *b & t in inches*

$S = \frac{6}{bt}\sqrt{m L b E}$; *E = 30,000,000 lbs/sq. in.*

	Mt	R_1	Im_1	R_2	R_3	Im_3	I_1	I_2	I_3	b Face	t Pitch	L	a	m	S
Fig. IV	300000	2	480	-	-	-	20000	-	-	14	4	1/16	30	120	32950
Fig. V	300000	2	480	6	3	1440	20000	1500	1000	10	5	1/16	43.9	160	42300

In general the impact stresses are kept within safety limits by reducing the electric current or steampressure at the first instand and therefore L and S reduces to zero before the maximum torque is applied. The total kinetic energy of all the moving parts is partially absorbed by the shafting, but not always and therefore breakage of coupling boxes and shafting during shock is to be expected.

The effects of shock are analog to the effects of an explosion. It is a well known fact, that an explosion may burst a pipe even if the pipe is open on both ends. The time element accounts for this. The gases developed during the explosion expand so rapidly that they have no time to escape through the open ends before the pressure has reached the bursting limit. Similarly we find that the resilience of a shaft is not always sufficient to take up sufficient energy in order to prevent destruction.

The following tabulation shows a comparision of stresses produced by impact in different gears having the same diameter at the pitch circle but different pitch and face. The weight of the gears is computed in accordance with current practice and therefore the values for $(\frac{r}{R})^2$ and m may be considered as comparative. The effect of the inertia of shafts and other rotating masses tend to increase the value of m and S. The time element is, however, the vital factor and accounts for the fact that machinery breaks down not always at its weakest link, but occasionally a stronger link breaks down even if designed on a basis of a very liberal safety factor.

$$S = \frac{L}{bT}\sqrt{6mbE}$$

$2R_1$ = pitch circle diameter = $\frac{120}{P}$; accelerating Time = T = 0.01 second; Speed constant = 50 FPM; allowable stress = 10000; $P = \frac{10000\,bt}{16.8}$; $C = 500$ ft./min.

Gear No.	Number of teeth	Pitch t inch	Face b inch	Back lash L inch	Weight of gear W lbs	Mass of gear $M = \frac{W}{32.2}$	$(\frac{r}{R})^2$ See Fig. III $R = R_1 + .1t$ in ft.	Reduced mass m $= (\frac{r}{R})^2 M$	Stress produced by impact S in lbs/sq. inch	Nominal HP by formula (1) and (2) $HP = \frac{PC}{33000}$
1	60	2	6	0.0625	550	17	.4	6.8	44600	108
2	60	2	10	0.0625	965	30	.5	15	51350	180
3	40	3	6.67	0.0625	1030	32	.5	16	43300	180
4	30	4	30	0.100	3865	120	.7	84	56125	1080
5	20	6	20	0.100	3865	120	.6	72	42400	1080

Gears No. 2 and 4 are subject to the highest impact stresses, although (as compared with No 3 and 5) they are considered the strongest gears when cumputing the nominal horsepower by means of Lewis formulas. It is therefore that we are still compelled to consider the cantilever formula not only on account of stress conditions but even more so on account of wear and change of shape of the tooth especially in steel mill practice. The impact stresses reduce 50% for h = .707t see Fig. I

The above examples illustrate the importance of proper mounting and gear adjustment and the possible breaking of a gear tooth, which is apparently ample strong, when subjecting same to shock or impact effect.

Most gear teeth are broken and stripped from the rim by forces due to impact or shock. Transmission of working load and improper lubrication are responsible for wear.

Stub teeth increase the strength and decrease the wear due to friction, but reduce the time of contact between two gear teeth and therefore increased strength is gained at the sacrifice of smooth running especially when the number of teeth is small. The number of teeth should be at least twenty, smaller number of teeth is permissible when teeth are cut and gears properly mounted and lubricated. The strength is doubled by shrouding

The kinetic energy of a rotating body follows from the relation $E_1 = \frac{Mv^2}{2} = \frac{I_m}{2}\left(\frac{2\pi n}{60}\right)^2 = \frac{Mr^2}{2}\left(\frac{2\pi n}{60}\right)^2$ in which $V = \frac{2\pi r n}{60}$ and r = radius of gyration in feet

n = Revolutions per minute

I_m = physical moment on inertia of gear in ft lbs

One Horse Power = 550 ft lbs per second

The average horse power required for accelerating a gear or any other rotating body from rest to normal speed (n) in (T_1) seconds is then

$$N = \frac{E_1}{550\,T_1} = \frac{1}{2}\frac{I_m}{550\,T_1}\left(\frac{2\pi n}{60}\right)^2 = \frac{I_m}{100{,}000}\frac{n^2}{T_1} = \frac{Mr^2}{100{,}000}\frac{n^2}{T_1} \qquad (6)$$

for example in the tabulation we find M = 120 for gear No. 4 As a special case

Let $\left(\frac{r}{R}\right)^2 = .76$; therefore $r^2 = .76R^2 = .76\left(\frac{19.1 + .1t}{12}\right)^2 = \frac{.76}{144} \times 19.5^2 = 2$

let the accelerating time from rest to normal speed $T_1 = 2$ seconds. In this case $n = 50$ then we find

$$N = \frac{Mr^2n^2}{100{,}000 \times 2} = \frac{240 \times 2500}{200{,}000} = 3 \text{ Horse Power}$$

$$\text{Constant Torque} = \frac{2N}{2\pi n} = \frac{6 \times 33000}{314} = 630 \text{ ft. lbs.} = 7560 \text{ inch lbs.}$$

The maximum horse power is $2N = 6$ and must be supplied by the driving apparatus generally an electric motor, this does not include energy required for other revolving parts such as motor armature, fly wheel, couplings, shafting and generally many other gears. It is therefore that the starting torque exceeds the running torque by several hundred percent and prevent starting in some cases.

The average horse power required or given off by the rotating parts when changing from a speed n_1 to n_2 in T_1 seconds is

$$N_1 = \frac{I_m}{100,000} \frac{(n_1^2 - n_2^2)}{T_1} \qquad (7)$$

The pulsation of energy during sudden speed variations is in most cases the cause of destruction of mechanical machinery, which is otherwise ample streng for the requirements of normal operation. Space, time and energy are to be considered in gear designing as much as in any other engineering problem. (Continued on Page 418)

Items of Interest

The Clark Controller Company of Cleveland, Ohio, announces the appointment of Mr. K. I. Clisby as their New York representative. Mr. Clisby will occupy offices in the Woolworth Building, New York City, New York.

The Pittsburgh Transformer Company, Pittsburgh, Pa., in their bulletin 2058 describes the largest self cooled transformers shipped complete in the history of the Electrical Industry. These transformers are 15,000 Kva and were shipped to the New York Edison Company at their East River Station. Each transformer weighed about sixty tons complete with oil. The radiating surface of each tank is one million twenty-five thousand square inches and each tank has forty-eight radiators. The Pittsburgh Transformer Company will be glad to mail you a bulletin on request.

The Crouse Hinds Company, Syracuse, New York, has just issued a very attractive folder which describes their vapor proof condulets. This folder is known as number 42 and may be had upon application.

The Edison Lamp Works of the General Electric Company, Harrison, New Jersey, has recently issued bulletin LD-117 C covering Calculation of the Lighting Installation. The synopsis is as follows: Recommended Foot Candle Levels, Selection of Reflecting Equipment, Location of Outlets and Mounting Height, Flux of Light, Point by Point (Candle Power) Method of Calculation, Bibliography.

Catalogue C-4, Combustion Engineering Corporation, New York City, New York, describes the Coxe Traveling Grate Stoker. A forced draft traveling grate stoker for boilers from 150 H.P. up will burn a wide range of fuels, but is especially adaptable to small sizes of anthracite coal and coke breeze, highly efficient with considerable capacity range. The catalogue is profusely illustrated with various installations of the Coxe Stoker, also typical evaporative tests of Coxe Stokers. These tests show the efficiency of the Coxe Stokers over a wide range of capacities. They were made in five different plants.

Mr. Yasudiro Sakai, Consulting Electrical Engineer, assisted by Mr. Masaharu Hashimura, begs

to announce the opening of his office at Room 465, Marunouchi Building, Marunouchi, Tokyo.

The Association of Iron and Steel Electrical Engineers wishes to acknowledge the receipt of reprints from the Science Reports of the Tohoku Imperial University covering the subjects of "The Relations between Space-Lattice Constant and Density of Iron-Nickel Alloys," by Atomi Osawa, "One the Surface Energy," by Mituo Yamada, "One the Specific Heat of Carbon Steels," by Saburo Umino, "The Use of Liquid Amalgams in Volumetric Analysis," by Kin 'ichi Someya.

The Kuhlman Electric Company, Bay City, Michigan, manufacturers of Kuhlman Power, Distribution and Street Lighting Transformers, announces the appointment of Mr. H. F. Darby, Jr, 1700 Walnut Street, Philadelphia, Pa., as direct Factory Representative in the Philadelphia District. For more than twenty years, Mr. Darby was with the Cutter Electrical and Manufacturing Company and during the last six years he was sales manager of that organization.

Catalogue No. 24, Benjamin Electrical Products, is a booklet containing 169 pages of data, in connection with industrial illumination, reflector sockets, lighting equipment, shade holder reflectors. protected lighting equipment, outdoor lighting fixtures, office lighting equipment, industrial signals, heavy duty water tight wiring devices, two-way plugs and specialties. Catalogue No. S4, Second Edition, Benjamin-Starrett Panel Boards and Cabinets for every lighting requirement has just been issued to the trade. Section 1 covers Fuse Lighting Panels, Section 2 Fuse Lighting Panels, Section 3 Increased Capacities and Added Equipment, Section 4 Residence Panels, Section 5 Numerical Index. Write the Benjamin Electric Manufacturing Co., Chicago, Ill.

The Wellman Seaver Morgan Company, Cleveland, Ohio, has issued a very attractive booklet, known as No. 85, describing the W-S-M Mechanical Gas Producer. They will be glad to furnish this bulletin upon application.

The September issue of the Trumbull Cheer is very interesting. An editorial that is really worthwhile is titled "Attitude of Mind." For a copy write the Trumbull Electric Manufacturing Company, Plainville, Conn.

Bulletin No. 28, Smoot Engineering Corporation, 136 Liberty Street, New York City, New York, covers the subject of Smoot Control, for Traveling Grate Stoker Fired Boilers. This bulletin describes the operation of the Smoot System of Control and is illustrated with photographs of installations and performance curves and charts.

The Research Department of the Brown Instrument Company has developed after several years' effort, a new Electric Flow Meter operating on an entirely new principle, never before used in Flow Meters. Several of these instruments have been under test for six or nine months on boilers in industrial plants for measuring steam flow and they have been giving excellent results.

Two of the largest synchronous motors in the world and the largest Scherbius equipment have been purchased by the Bethlehem Steel Company for the new continuous skelp and sheet bar mill for its Sparrows Point plant near Baltimore, Md.

The synchronous motors are rated 4000 h.p., 83.3 r.p.m, and 6500 h.p, 187½ r.p.m., 6600 volts, three phase, 60 cycles. These motors are the largest ever built for main roll drive with the exception of the 9000-h p. General Electric motor in the River Furnace plant of the McKinney Steel Company at Cleveland.

The Scherbius equipment consists of a 6700/-5000/3320 h.p., 500/375/250 r.p.m. induction motor, which is the largest equipment in the world using this type of adjustable speed drive.

The mill is also driven by a 2600/2600/1570 h.p, 320/275/160 r.p.m. adjustable speed direct-current motor.

The generator for the direct-current motor and the Scherbius machines for the induction motor are all driven by one synchronous motor, making, with the exciter, a five-unit equipment.

All of the electric equipment is being manufactured by the General Electric Company.

Gerard Swope, President of the General Electric Company, announced a further reduction in the prices of Mazda lamps, effective September 1, 1926, amounting to about 7 per cent on the sizes generally used of the new standard line of lamps and approximately 5 per cent on all types.

This is the eighth reduction of Mazda lamp prices since 1920. This reduction means a saving to the public of approximately $4,000,000 a year.

The prices of Mazda lamps are now 44 per cent below the 1914 prices which compare with a 65 per cent increase in the average cost of commodities since that year.

The reductions in Mazda lamp prices have been made possible primarily by better manufacturing methods and by standardization and simplification of lamp types.

Two electric generators, each nominally rated at 90,000 kilowatts at 90 per cent power factor or 100,000 kilowatts at unity power factor, the world's largest in both capacity and physical dimensions and to be driven by the two largest single turbines ever made, are being manufactured at Schenectady, N. Y., by the General Electric Company for the Southern California Edison Company.

Two other unusual features have been incorporated in these machines. The armatures are being built with special heavy construction so as to be gas-tight, for the possible future adoption of the new system of hydrogen cooling. The machines are also the first to have a double-flow low-pressure end and four vertical condensers; with advantages of a simplified foundation and increased space for removal of condenser tubes.

The armatures of these generators, each weighing 330,000 pounds, are of such size that they will be assembled at Los Angeles. Even if railroad cars

with a capacity of 165 tons were available, it would be impossible to ship them by rail because of track, bridge and tunnel clearances.

The heaviest pieces to be shipped from Schenectady will weigh 230,000 pounds. These will be the revolving fields of the main generators. The total length of the turbine-generators will be 103 feet each and the total weight of each 1,650,000 pounds.

These machines will produce current at 16,500 volts; the highest with turbine-generators at the present time is 14,000 volts. Going above this figure to 16,500 volts means simplification of the switching problem and a reduction in the cost of the transformers which will be used in stepping up the voltage to still higher figures before the current is fed into the transmission system.

The turbines are of the tandem-compound type, with a rating of 94,000 kilowatts at 90 per cent power factor or 105,000 kilowatts at unity power factor. A tandem-compound steam turbine is in reality a single machine in that all of the equipment is mounted on the same shaft, that only one generator is used, and that the flow of steam is continuous. In the other type of turbine, the cross-compound, there is a division of units, with high pressure steam driving one electric generator and low pressure steam driving a second generator on another shaft.

The two generators which are being built for the Southern California Edison Company are not only the largest single machines in the world, but they are also larger than the individual elements of any cross-compound turbine yet built or under construction anywhere in the world. The record for size of single machines ever shipped is now held by the 60,000-kilowatt units built by the General Electric Company for the New York Edison and Buffalo General Electric companies.

Each of the main generators operates at 1500 revolutions per minute; they will produce current at 16,500 volts and 50 cycles. In addition to the main generators, each unit is equipped with a house service generator on the same shaft, rated at 4,000 kilowatts at 80 per cent power factor or 5,000 kilowatts at unity power factor.

The steam turbines driving the generators receive steam at a pressure of 400 pounds gauge and a temperature of 725 degrees Fahrenheit. The exhaust steam is at a pressure of one inch absolute, so that practically all of the energy of the steam is extracted by the turbines. The boilers which will supply steam to the turbines will be so constructed that they can use either natural gas or oil as fuel.

Two years ago a record for turbines in the west was set by the two 35,000-kilowatt units supplied by the General Electric Company for the Long Beach station of the Southern California Edison Company. This record was broken by the General Electric 52,800-kilowatt unit which was recently started in operation in the same station; and now a record is to be broken by the Southern California Edison Company, not only for the west, but for the world.

A new development in electric arc welding equipment is the assembly of General Electric gas engine driven welders on Fordson tractors for portable use at points remote from power lines. The General Electric Company does not market the complete outfit.

In such a combination, the same gas engine drives both the tractor and the generator which supplies the current for the welding electrodes. The tractor is equipped with rubber tires and can be driven to the job at a speed of from 15 to 18 miles per hour. The belt is then connected to the generator and the outfit is ready to weld.

Mr. C. R. Moore, an active member of this Association, employed by the Berwind White Coal Mining Company, Windber, Pa., in the capacity of Superintendent of the Electrical Department, died September 4, 1926. Mr. Moore was formerly associated with the Cambria Steel Company, and was well known throughout the Iron and Steel Industry. Many of his friends and the entire membership as well will be sorry to learn of Mr. Moore's death.

Mr. E. Swift Newton, Assistant General Manager of Sales, The Cutter Company, Nineteenth and Hamilton Streets, Philadelphia, Pa., left on the steamer George Washington, Wednesday, September 1 for a six weeks' trip through the principal European cities.

Mr. E. Trexler, Comb. Engineer, Cambria Works, Bethlehem Steel Co., Johnstown, Pa., left September 4, for an extended trip through Europe.

The Roller-Smith Co., 233 Broadway, New York, has just issued new bulletins, Nos. 110 and 150, covering their new types HTD and HTA instruments.

The HTD instruments in Bulletin No. 110 comprise direct current ammeters, voltmeters and voltammeters.

The HTA instruments in Bulletin No. 150 comprise alternating current ammeters, voltmeters and single phase wattmeters.

The outstanding features claimed for these new instruments (both Types HTD and HTA) are as follows:

1. Small enough for the pocket, tool kit or traveling bag.
2. Accurate enough for all ordinary tests and rugged enough to withstand extremely hard service.
3. Light in weight, very compact and handsome in appearance.
4. The lines are so complete and the instruments themselves are so accurate and dependable that they can be used very largely where heretofore only large portable instruments were employed.

The Roller-Smith Company, 233 Broadway, New York, N. Y, announces the appointment of the following new agents:

The Robinson Sales Company, Polson Building, Seattle, Washington, for the State of Washington and most of the State of Oregon. The Robinson Sales Company has been handling Roller-Smith apparatus on a sub-agency basis for quite some time and, therefore, is well equipped to represent the Roller-Smith Company in the territory designated.

The Ashida Engineering Company, Ltd., Daini, Osaka, Japan for Japan (Including Koera and Manchuria). The Ashida Engineering Company is one of the most important concerns in Japan importing electrical apparatus from the United States and their experience has been along lines such as are made by the Roller-Smith Company, namely, electrical measuring and protective apparatus. Through this new connection the Roller-Smith Company confidently expects a large increase in its Japanese business.

(Continued from Page 415)

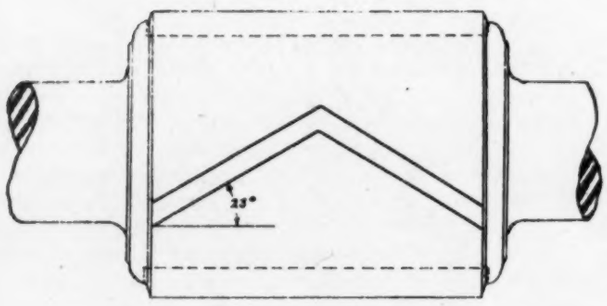
HERRINGBONE versus SPURGEAR PINIONS

When used on a 40" Reversing Mill.

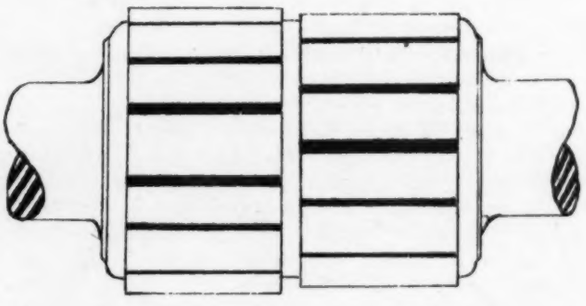
comparisons of properties, when staring torque M_t = 1200000 ft.lbs.

GIVEN DATA - STUB TEETH TOTAL HEIGHT 60% OF CIRCULAR PITCH								
Gear No.	Type of Gear	Number of Teeth $n_1 = n_2$	Circular pitch inches t	Face in inch b	Pitch circle diam. inch	Rev. per min.	Speed C ft/min.	Allowable working stress lbs/sq.in.
1	Herringbone shrouded on ends	17	7.392	51.25	40	60	628	10000
2	"	18	7.3304	51.25	42	60	660	10000
3	Spur staggered teeth at ½ pitch shrouded in middle and ends	14	8.975	48	40	60	628	10000
4		15	8.796	48	42	60	660	10000

GIVEN DATA - (Case A with shrouds) (Case B without shrouds)							
Gear No.	Back lash in inches L	Distance point of impact to weakest section = l_0 inch		Thickness of tooth at weakest section		Distance weakest section to top of tooth = l inch.	
		l_0 Case A	l_0 Case B	Case A h inch.	Case B h inch.	Case A l	Case B l
1	.20	1.3	2.72	3.6	3.95	2.125	3.54
2	.20	1.3	2.63	3.58	3.92	2.075	3.43
3	.20	1.8	3.80	4.28	4.80	2.545	4.35
4	.20	1.8	3.70	4.25	4.80	2.575	4.45



Herringbone Pinion.
FIG. 6.



Spur Pinion Staggered Teeth.
FIG. 7.

CALCULATED DATA (Combined moment of Inertia I_1 = 60000, See Fig. 4)

Gear No.	Working Load $p=\frac{10000bh^2}{6l}$ in Pounds		Nominal Horse Power $HP=\frac{PC}{33000}$		Weight of Gear W in Lbs	Mass of Gear $M=\frac{W}{32.2}$	Physical Moment of inertia of gear Im in ft/lbs	Distance point of impact to center of gear. R in feet
	Case A	Case B	Case A	Case B				
1	520900	378000	9470	6880	30740	955	1022	1.77
2	527600	382000	9590	6930	32850	1020	1213	1.85
3	575800	424000	10470	7700	30740	955	1022	1.82
4	561200	414500	10200	7520	32850	1020	1213	1.89

Gear No.	Radius of Gyration $r=\sqrt{\frac{I_m}{M}}$	Reduced Mass $m=M\frac{r^2}{R^2}$	Acceleration $a=\frac{Mt}{I_1}$ ft/sec²	Impact Stress in Lbs/square inch. $S=16400\sqrt{\frac{mgL}{bht_0}}$ Case A	Case B	Acceleration time in seconds T	T_1	Duration of contact or number of teeth in action T'
1	1.03	323	35.4	50700	33500	.03	.314	$T'=2.93$
2	1.09	354	37.0	54300	36500	.03	.314	$=2.98$
3	1.03	306	36.4	40200	26200	.03	.314	$=2.64$
4	1.09	339	37.8	43300	28400	.03	.314	$=2.74$

$T'=.5\sqrt{\frac{n_1}{2}}+\frac{b\tan 23^\circ}{2t}$ for gear No. 1 & 2 and $T'=\sqrt{\frac{n_2}{2}}$ for gear No. 3 & 4

The extra strength of the apex of the truss of the herringbone tooth was not considered in case A and taken equal to a center shroud up to 1/8 inch below the pitchline in case B, similar the height of the shrouds for the spur gear. T' gained 100% due to staggered and herringbone teeth.

In case of mill pinions the teeth are only subject to half the starting torque, that is PR should be equal or larger than 600000, which condition is fulfilled in case A for all four Gears. The tooth pressures were computed on a basis of only one tooth in action and are therefore con-

siderable lower during actual operation, provided the gears are kept in line. The impact stresses and duration of contact indicate that the spur gears are the most suitable for the purpose, especially in case of a reversing mill, were gear teeth are subject to blows at the rate of 20 to 60 per minute. The herringbone gears wear faster than thespur gear and should therefore not be used for reversing mills for the wear increases the backlash, which causes still greater losses due to impact. When the tooth becomes very rigid like in the case of herringbone gears, then the impact energy is converted into heat. The horse power in case A for spur gears is 70% higher than we would find by means of formula (1) and (2) due to special shape of teeth used for this kind of work. The tooth pressure ~~is~~ figured by means of the formula for herringbone gears (1) is about 17% within the result shown under case A and 40% within the result case B for herringbone gears.

This shows that formula 1 may be used for spur and herring bone gears equipped with stub teeth--40% strength is gained by half shrouding and 100% by full shrouding. *By method shown in derivation of formula (3), We find:*

The formula $S=\frac{3}{\sqrt{b h l_o}}\sqrt{maLE}$ reduces to $S=\frac{6}{bt}\sqrt{mabLE}$ (3) *for* $l_o=\frac{t}{2}=h$

In general $S=16400\sqrt{\frac{maL}{bhl_o}}$ *for* $E=30,000,000$ (8)

Within the elastic limit we have then

1. The impact stresses vary inversely with the square root of the thickness, that is when the thickness of the weakest section (h) of the tooth increases from .5 to .707 t, then the impact stresses decrease $100(1-\sqrt{\frac{.5}{.707}})$ or 16 percent.
2. The impact Stresses vary ~~inversely~~ square root of with the distance of the point of impact to the weakest section therefore shrouding tends to increase impact stresses due to decrease of l_0. The pressure between the teeth becomes very hight when l_0 becomes small and therefore lubrication ineffective, furthermore, heat is generated equivalent to the impact energy (one heat unit or B.T.U.= 778 ft.lbs) causing rise in temperature of lubricants and gear teeth with the

result of additional wear and lower efficiency of the drive.

3. The impact stresses vary inversely with the pitch (t) in general, for h and l_0 are proportional with the pitch as illustrated in the derivation of formula (3) in which $l_0 = h = \frac{1}{2}t$.

4. The impact stresses vary inversely with the square root of the face or width (b) of the tooth; directly with the square root of the back lash (L) and the square root of the modulus of ELASTICITY (E)

5. The line of contact between the teeth of spur gears is always straight and paralel with the base of the teeth and axis of rotation, therefore minimum wear and maximum afficiancy. The load pressure and elasticity of metal changes the line of contact to a rectangular area.

6. The line of contact between the teeth of bevel or conical gears is straight when running idle, but not when loaded on account of varying deflection along the tooth as the tooth pressure varies along the line of contact due to line of contact not being parallel to the axis. The change of the line of contact from straight to all kinds of curved lines causes more frictional wear than in the case of spur gears and therefore less efficiency. Area of contact not rectangular.

7. The line of contact of herringbone gears is curved and changing shape under all conditions of load and speed and therefore the worst performance of all for so far as friction loss and wear concerns with the result of very low efficiency in some cases. The herring bone gear has however the unquestionable feature of great strength and smooth running for the helical tooth represents the running conditions of a very large number of spur gears of very small face mounted on the same shaft; the centers of the teeth of the different gears are staggered so to represent a shrewline or helical. Records show good service when the right kind of lubricant is used.

In many instances the smooth running of the gears is a prime factor regardless of wear and efficiency, for instance in case of wire drawing and in some finishing mills of structural steel, but it should be kept in mind, that it is a paying proposition to replace such gears often for the extra wear causes rapid decrease in efficiency.

8. The impact stresses vary directly with the square root of the acceleration and indirectly with the acc. time. (Formula 4)

9. The impact stresses vary directly with the square root of the reduced mass (m) of the gear.

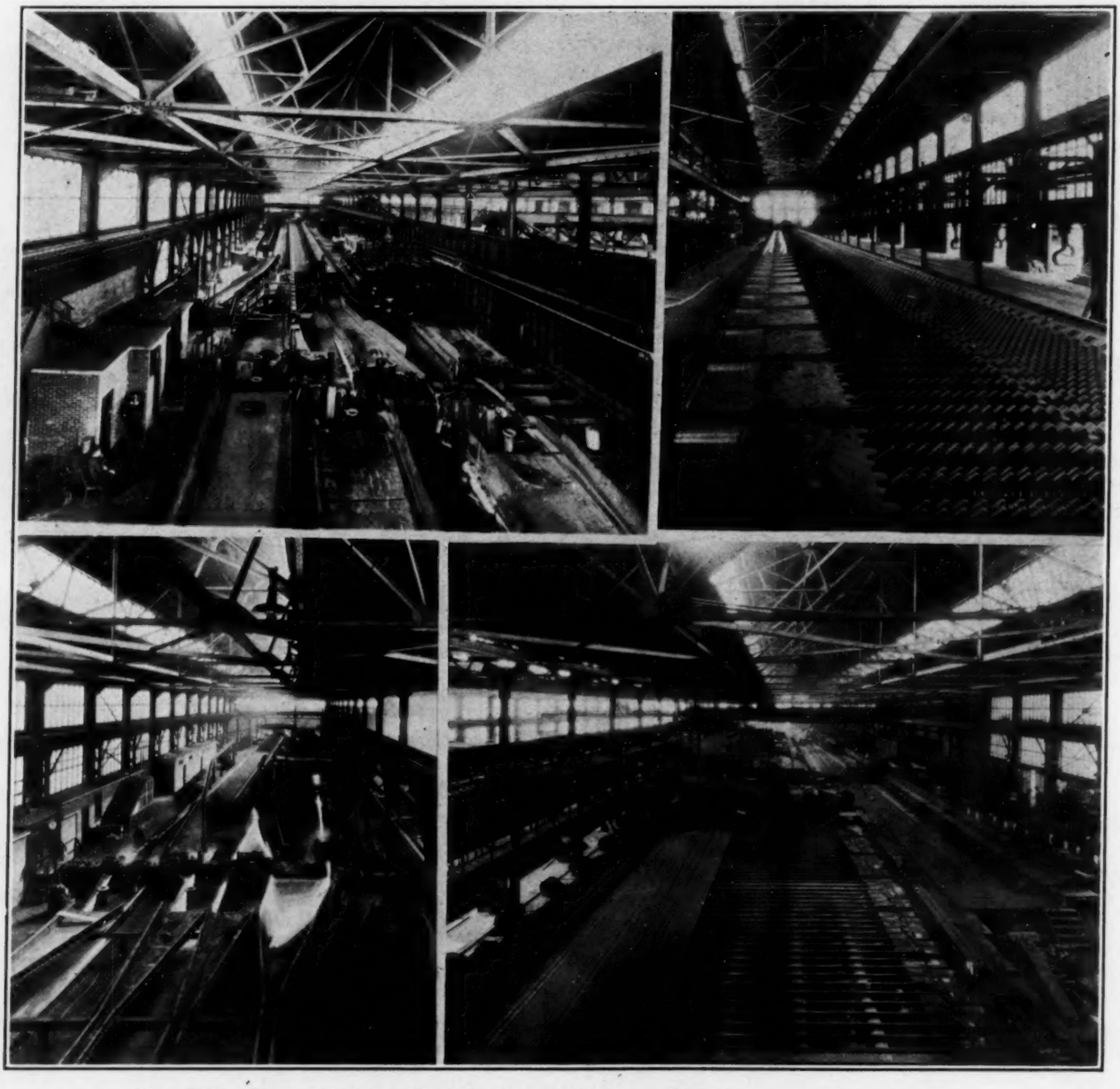
4.3026 E.K. GARY U.S.A.

Inspection Trip
Cambria Works—Bethlehem Steel Company
Johnstown, Pennsylvania

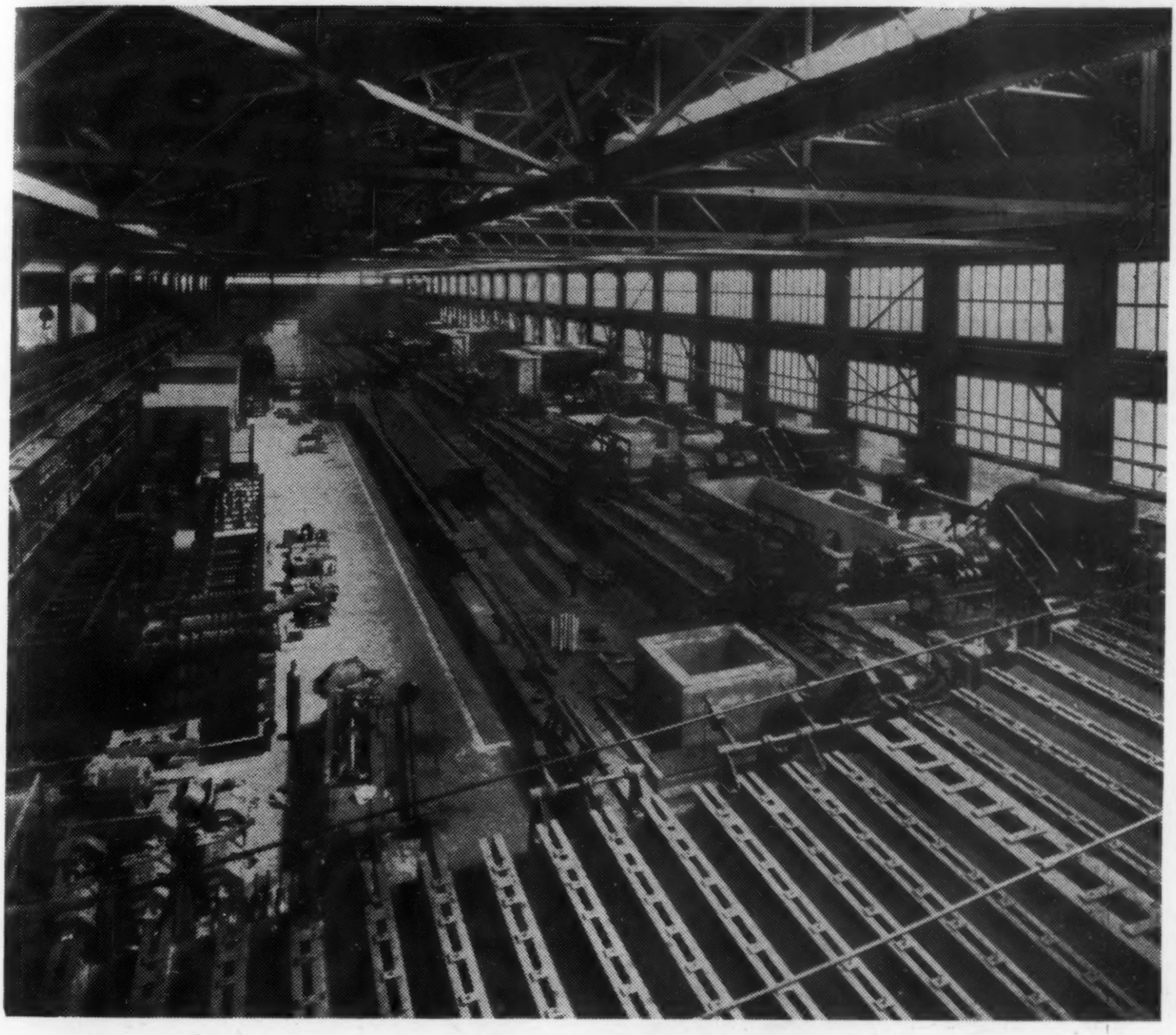
Saturday, September 25th, 1926, Mr. L. R. Custer, General Manager, Cambria Works, Bethlehem Steel Company, Johnstown, Pa., will act as a host to the engineering profession of the Iron and Steel Industry, who will make an inspection of the Cambria Works in general, but particularly the four new bar mills which have recently been placed in operation at the Gautier Plant of the Cambria Works.

These four new mills represent an investment of millions of dollars and are the handiwork of the engineering and operating staffs of the Bethlehem Steel Company. These mills are acknowledged to be among the most modern rolling mills of today and represent in every detail the latest developments in the mechanical, combustion, safety and electrical arts.

In the construction of these four new mills the Bethlehem Management did not overlook a single opportunity to provide for the welfare and the safety of the employees who operate these departments. One particular feature that represented an investment of at least one hundred thousand dollars is the Safety Man Way which is an underground passage for the workmen to pass from one mill to another and designed with a view of affording perfect ventilation and plenty of room. The sanitary arrangements of the four new mills could not be improved upon.



New Mills, Gautier Division, Cambria Plant, Bethlehem Steel Company, Johnstown, Pa.



New Thirteen Inch Bar Mill

The Cambria Plant at Johnstown, Pa., is one of the oldest and perhaps one of the best known steel plants in this country. It has an annual pig iron capacity of almost two million tons per year and an annual ingot capacity very close to one million eight hundred thousand tons. It is located in the heart of the bituminous coal region of Pennsylvania and is one of the few steel making plants in the world where coal is taken direct from the mines into the coke ovens without storage or transportation.

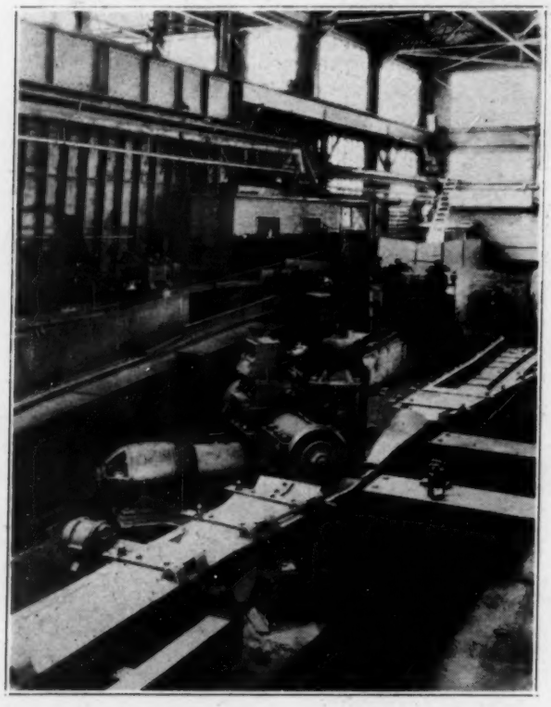
The Cambria Plant is operating at the present time ten blast furnaces and in this connection was one of the first steel plants in America to operate a complete automatic skip hoist device. The Cambria Plant also operates four Bessemer converters, twenty-nine open hearth furnaces, fifty heating furnaces, approximately fifty rolling mills and has four hundred and ninety by-product coke ovens, eighty-nine gas producers, five mixers, five cupolas, one hundred and twelve water tube boilers, four thousand motors and a connected load of one hundred and sixty-nine thousand electrical horse power.

The most important part of Bethlehem's rebuilding program at Cambria was the construction of the four new Gautier bar mills, together with the facilities for handling, warehousing and shipping the general products of the Gautier works. These mills with the existing units have a capacity of sixty thousand tons per month of commercial bars, light structural material, mine track accessories, agricultural implement parts and standard and special sections for automobiles and many other purposes.

One of the important units at the plant is the railroad steel freight car department which obtains its requirements of car wheels, axles, beams, plates and other steel materials from other departments within the plant. The capacity of the car department is being increased to over one thousand five hundred cars per month by rearrangement of the shops for quantity production and the construction of a new car paint shop equipped with the most modern appliances. This department operating at capacity will require over two hundred thousand tons of corporation's products per year.

Another important unit is the rod and wire department which has a capacity of twelve thousand five hundred tons per month of rods, wire and wire products of all kinds, including nails and fencing.

The plant also specializes in the manufacture of wheels and axles, rolled steel blanks for gears, fly-

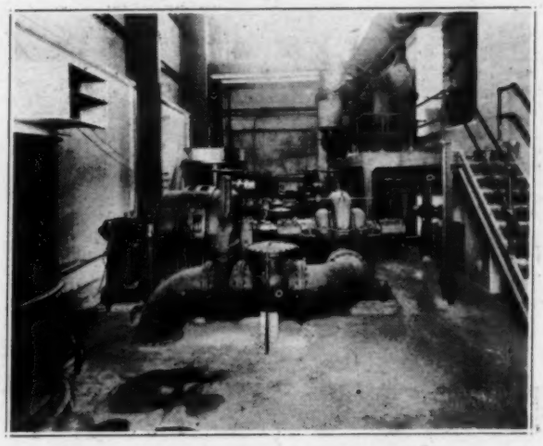


High Speed Shear New 10" Mill, Gautier Works

wheels and other circular forgings, sheet bars, slabs, billets, steel mine ties, structural shapes and steel plates.

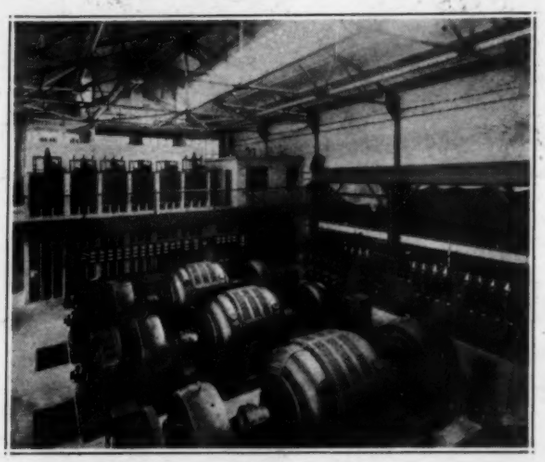
The equipment of Cambria Plant, at Johnstown, Pa., is as follows:

Blast Furnaces, Lower Division (formerly called Cambria Plant); 4 stacks; B, 91′ 6″ x 21′ 2″, blt. 1853-54, last reblt. 1924; D, 90′ x 22′ 4″, blt. 1853-4, last reblt. 1924; E, 92′ x 24′, blt. 1873-76, last reblt. 1925; F, 86′ 9″ x 22′ blt. 1879, last reblt. 1925. Franklin Division (formerly called Franklin Plant): 5 stacks; G, 85′ 9″ x 22′, blt. 1903-6, reblt. 1914, relined 1924; H, 85′ 9″ x 22′, blt. 1906-07, reblt. 1914, relined 1922; J, 90′ x 22′, blt. 1916, relined 1921; K, 89′ x 22′ 6″, blt. 1916-17, relined 1924; L, 89′ x 22′ 6″, blt. 1917, relined 1924; 35 stoves (4 center-comb. 99′ 6″ x 20′ at B: 23 side-comb. 100′ x 24′ of which 4 each at D, F, J, K, and L and 3 at E: 8 center-comb. 100′ x 24′ of which 4 each at G and H): 18 blowing engines (6 horizontal steam, 6 vertical steam, 5 turbo blowers,



Circulating Pumps for Spray Pond, New Power House

1 gas) 594,000 cfm.; 112 water-tube boilers, 38,780 H. P. furnish power also to Steel Depts. and rolling mills; 5 Heyl & Patterson double-strand pig casting mach.; Dwight & Lloyd (2 strand) sintering plant for flue dust, annual cap., 150,000 tons. By-product coke; Lake ore. Product: bessemer, basic and foundry pig iron, and ferro-manganeses, annual cap., 1,740,000 tons. By-product Coke Dept.: Lower Division, Rosedale,



Sub-Station for New Mills, Gautier Works

208 by-product coke ovens (120 Cambria improved 88 Semet-Solvay): Franklin Division, 282 by-product coke ovens (92 Koppers, 190 Cambria; by-product recovery plants and Semet-Solvay benzol plant; annual cap., (490 ovens) 1,848,000 net tons coke; 7,500,000 gals. light oil.

Steel Dept.: Lower Division, blt. 1853, first bessemer steel July 10, 1871, first O. H. steel 1879; 4

bessemer converters (12½-ton); 7 B. O. H. fur. (four 40-ton, three 50-ton); 1 A. O. H. fur. (50-ton); Franklin Division, blt. 1900-01, 21 B. O. H. fur. (sixteen 75-ton, five 100-ton); fuel in O. H. producer gas

Subway Safety Entrance New Gautier Mills

and tar, 89 gas producers (Morgan, Taylor, Hughes); 5 mixers (one 1,300-ton, one 300-ton, three 250-ton): 5 cupolas for pig iron, 2 cupolas for spiegel. Foundry for gray-iron castings (4,000 tons), ingot stools (14,000 tons) and brass castings (700 tons) for own use and for sale.

Rolling Mill Depts.

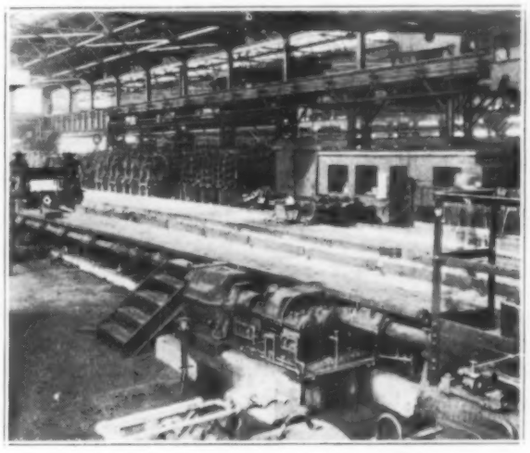
Lower Division: eight 1-hole soaking pits; 16-heat. fur.; 48″ 2-h. 1-st. blooming; 40″ 2-h. 1-st. blooming; 22″ 2-h. 4-st. and 1-8″ 2-h. 8-st. cont. sheet bar and billet; 30″ 3-h. 4-st. structural; 22″ 3-h. 3-st. structural; 28″ 3-h. 3-st. rail; 22″ 2-h. 1-st. axle; axle forge dept.

Franklin Division: 15 soaking pits (nine 1-hole, six 4-hole); 15 heat. fur.; 40″ 2-h. 1-st. blooming; 34″

General View Gautier Mills

2-h. 2-st. universal slabbing; 32″ 2-h. 1-st. blooming; 34″ 2-h. 1-st. billet; 36″ x 134″ 3-h. sheared plate mill; rolled steel wheel dept.; steel freight car dept.; bolt, nut and rivet dept.

Gautier Division: 19 heat. fur.; 28″ 3-h. 1-st. and 22″ 2-h. 1-st. bar; 20″ 3-h. 1-st. and 20″ 2-h. 1-st. bar; 18″ 3-h. 2-st., 14″ 3-h. 5-st. and 14″ 2-h. 1-st. bar; 13″ 3-h. 3-st. bar; 12″ 3-h. 4-st. and 12″ 2-h. 1-st. (No. 1, 12″ bar); 16″ 2-h. 6-st. and 12″ 2-h. 2-st. (No. 2, 12″ bar); 18″ 3-h. 1-st., 10″ 3-h. 6-st. and 10″ 2-h. 1-st. bar; 9″ 3-h. 4-st. and 9″ 2-h. 2-st. (No. 1, 9″ bar); 9″ 2-h. 3-st. cont., 9″ 3-h. 1-st., and 9″ 2-h. 3-st. (No. 3, 9″ bar); 12″ 3-h. 1-st., 8″ 3-h. 3-st. and 8″ 2-h. 2-st. (No. 1, 8″ bar); 12″ 3-h. 1-st., 8″



New 13″ Mill Gautier Works

3-h. 3-st. and 8″ 2-h. 2-st. (No. 2, 8″ bar); 10″ 2-h. 6-st. and 8″ 2-h. 3-st. (No. 3, 8″ bar); 24″ x 67″ universal plate mill; agricultural implement dept.; frog and switch dept.; splice bar shop; rail anchor shop; shear shop.

PROGRAM

Special Train Will Leave Union Station, Pennsylvania Railroad, 8:00 A. M., Eastern Standard Time. Train Will Arrive at Johnstown About 10:15 A. M.

Everyone will disembark from the special train at Johnstown Station, descend steps Johnstown Station through subway station to Washington Street. Up Washington Street turning left to transportation office of the Bethlehem Steel Company, through transportation office to Railroad yards, Gautier Works, through Railroad yard to 14″ mill of billet storage building, through billet storage building to approach to sub-station.

Note: On your right, main drive shaft of 14″ mill, heating furnaces and magnetic control platforms. Enter sub-station.

Sub-station Equipment

5—2000 KW Motor Generator sets driven by 6600 Volt Synchronous Motors.

One bank 4000 Kva 6600 Volt Primary 2200 Volt Secondary Transformers.

One bank 1200 Kva 6600 Volt Primary 220 Volt Secondary Transformers.

Power for this sub-station is supplied from main 6600 Volt, 1,000,000 circular mil bus lines, that are tapped in the switching tower located just east of the sub-station. This tower is equipped with four 2000

ADVERTISING PAGES REMOVED

ampere, 6600 Volt oil circuit breakers with necessary disconnecting switches located on each side of each tap so that either or both bus lines may be disconnected on the east or west side of tower. Current is brought from the tower to the sub-station through 12 three-inch aluminum conduits, each pipe supporting a 1,000,000 C. M. 13,000 Volt Cambric insulated cable which terminate in 6—2000 ampere reactors, then to main or auxiliary bus.

The low voltage switchboard consists of 43 panels. The main DC bus located in basement consists of positive, negative and starting bus. This bus extends through sub-station to a 48″ concrete bus tunnel which is 580′ long. The positive and negative bus each consists of 18 bars solid copper 6″ x ¼″. The starting bus consists of 4 bars solid copper 4″ x ¼″. Conduits carrying the starting control circuits from the main drive DC motors are also located in this bus tunnel. Located in the basement are also 15 Motor Driven rheostats and current transformers for 6600 volt circuits.

The equalizer bus for the 10 generators is a ring bus with one cross connection in the center. Pedestals for the equalizer switches are located on main floor above this bus. This entire station and switching tower is controlled from the fifteen panel bench board, power for all control circuits is supplied by a storage battery station containing 120 cells.

Included in the switching equipment is:

9—1200 ampere 6600 volt oil circuit breakers.
3—2000 ampere 6600 volt oil circuit breakers.
4—600 ampere 2200 volt oil circuit breakers.
5—400 ampere 6600 volt oil circuit breakers for starting motor generator sets.

The AC bus layout includes 6600 volt main and auxiliary buses, starting bus and 2200 volt bus. The bus system of this station, tunnel and motor houses required 48,400 feet of bus bar, which weighed 226,923 pounds.

In connection with sub-station is located a 3,000 HP 250 Volt DC twin motor driving eight stands of the 14″ mill. Starting equipment for this motor (and also for the 1500 HP 250 Volt DC Motor which drives 2 stands of 14″ mill) is located in this sub-station.

Leaving sub-station you will not 14″ mill stands, hot saws, hot beds, and main operating pulpit.

Enter Safety Man Way leading to southside of 14″ mill. At Safety Man Way exit soutside 14″ mill, note the 1500 HP 250 Volt DC Motor Drive for 2 stands of 14″ mill.

Turning right enter 13″ mill facing hot beds.

The next point of interest is the 1500 HP 250 Volt DC Motor driving the finishing stands of the 13″ mill. The control for this motor and also the 3,000 HP twin motor which drives the roughing stand is located in this motor room.

Proceed then through the mill to heating furnaces entering the Safety Man Way which leads to southside of 13″ mill. Ascend stairway and pass hot billet, shear and No. 1 stand continuing through 13″ mill to the 3,000 HP 250 Volt twin Motor which drives the first eight stands of the 13″ mill.

Passing the mill oiling system you will notice on the left the magnetic control platform and mill hot beds. Passing product shear into shear building, continue into Nos. 1, 2 and 3 finishing and shipping buildings, you will notice to the left finishing beds, shears and scales, of the 14″ mill. Continuing through the finishing building turn right re-entering shear building at 10″ mill product shear and scale, passing into 10″ mill, proceed along hot bed, and note the 85 Motor Driven Cone Rollers, coil conveyor, coiling machines, flying shear. Then to motor house containing 900 HP 250 Volt DC Motor driving No. 9 and 10 stands of the 10″ mill. West of the Motor House is Master Control Pedestal. Passing around end of this mill notice the safety looping bar tables. Enter main motor house where are located 1—17, 50 HP 250 Volt DC Twin Motor, which drives 4 stands of the 10″ mill. Also a 2000 HP 250 Volt DC Double Speed Range, Motor driving first four stands of this mill. The switchboard located here controls the main drive motors also the two small motor generator sets which supply power for the cone roller motors on the hot beds. One of of these motor generator sets can be used for emergency service on the cone roller of the 10″—9″ or 13″ mills. Th rating of these motor generator sets are Generator 19.6 to 50 KW 81.5 to 211 Volts 512—1320 RPM, Motor 35 to 80 HP-DC 230 Volt DC 512-1320 RPM.

Leaving Motor House pass oiling system and heating furnace on left and 10″ billet storage building on right. Passing under billet roller run to furnace continue along 10″ mill hot bed to shear building, enter Safety Man Way leading to 9″ mill.

Passing 9″ product shear and scales continue along hot bed, notice cone rollers to left, also 500 HP 250 DC Motor which drives 9 and 10 stands of this mill. Notice control pedestals for main drive motors. Proceed around west end of this mill to main control room and motor house which contains 1,000 HP 250 Volt DC Motor driving four stands of this mill. Directly east of this motor house is a duplicate motor driving first four stands of this mill. You will then pass through 9″ mill billet storage building, to main entrance Gautier Works, entering Main Safety Man Way leading to northside of new mills, where luncheon will be served, and a special train in waiting to convey the party on a special trip to the new isolated phase power house and many other points of interest in the Cambria Plant.

Special train will return all of the Inspection party to the closest point to the building where the dinner will be served.

The Dinner will start promptly at 5:00 and will close promptly at 8:10 leaving the Inspection Party enough time to board the special train at the Johnstown station which will leave Johnstown promptly at 8:30 P. M. Eastern Standard Time arriving in Pittsburgh 10:15 Eastern Standard Time.

Mr. L. R. Custer will be assisted by the following operating heads of the Cambria Works to entertain the engineers and executives who will make this inspection trip.

Mr. W. E. Miller, Supt. Elec. Dept.
Mr. C. L. Baker, Management's Repr.
Mr. H. M. Prossett, Supt. Coke Plants.
Robert McEldowney, Supt. Blast Furnaces.
Mr. L. F. Quigg, Supt. Franklin Steel Works and Mills.
B. F. Faunce, Supt. Steel Car Shops.
P. J. Scott, Supt. Steel Wheel Works.
D. S. Muckley, Supt. Gautier Works.
H. H. Phillips, Supt. Rod & Wire Works.
H. E. Trout, Supt. Railroad Department.
L. H. Winkler, Metallurgical Engineer.
J. V. Symons, Supt. Lower Steel Works and Mills.
F. E. Howells, Supt. Mechanical Dept.
S. D. Evans, Works Accountant.
F. E. Thompson, Supt. Order and Shipping Dept.
E. O. Murray, Asst. to Purchasing Agent.
R. H. Stevens, Chief Engineer.

TECHNOLOGY DEPT.

FUEL — ELECTRICITY — MACHINERY — METHODS

EMPIRE BUILDING, PITTSBURGH, PA.

To Educate the Engineer in Industry

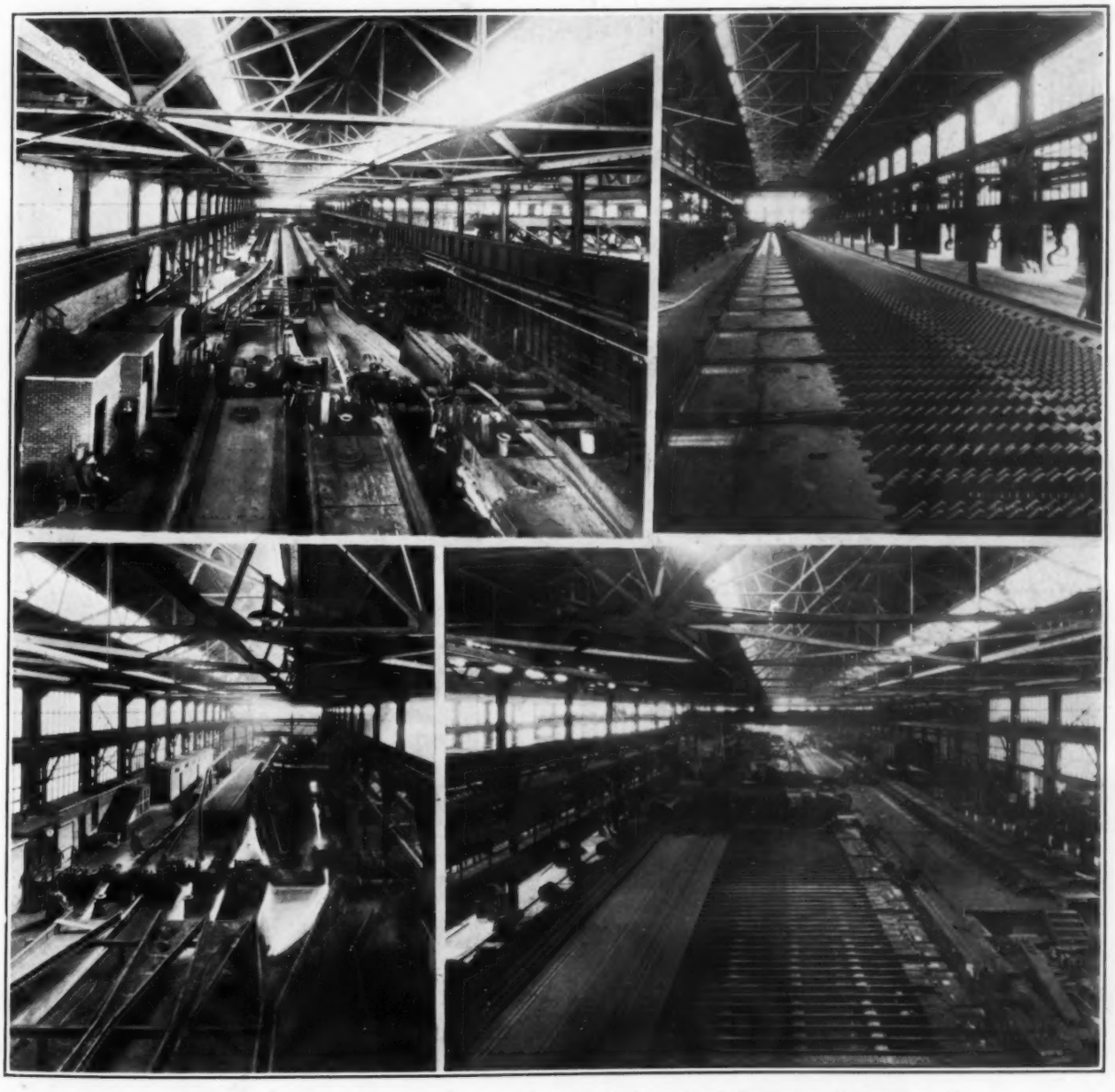
Containing the Proceedings of the A.I.&S.E.E.

INSPECTION TRIP

Bethlehem Steel Company

JOHNSTOWN, PA.

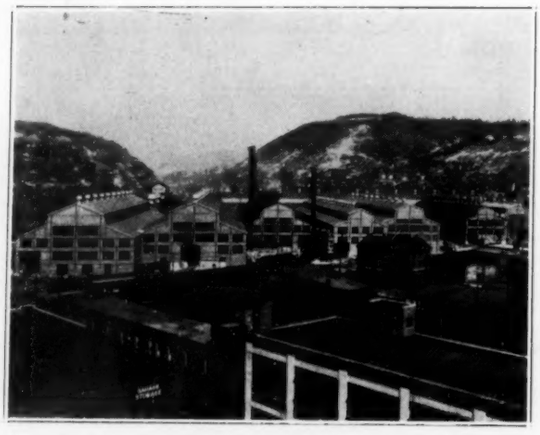
September 25th, 1926



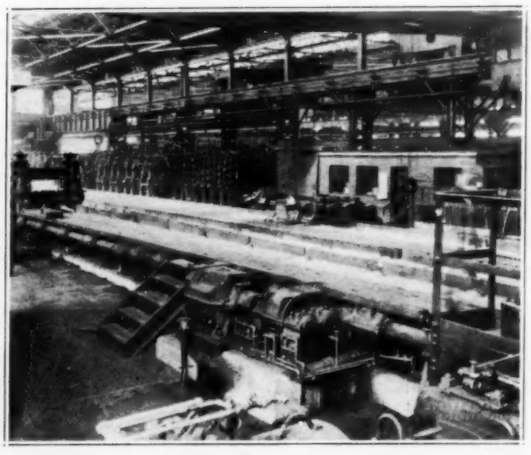
New Mills, Gautier Division, Cambria Plant, Bethlehem Steel Company, Johnstown, Pa.

An Invitation to Attend Our Trip to

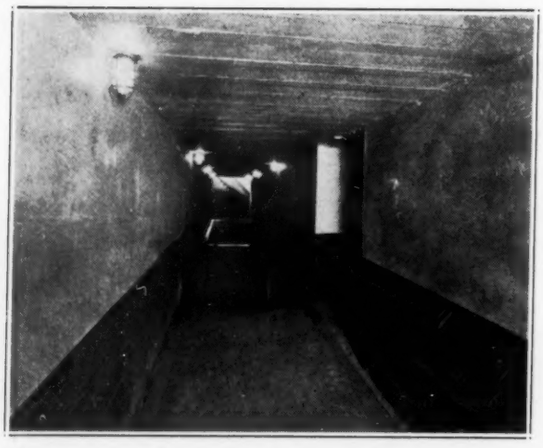
BETHLEHEM STEEL COMPANY



General View Gautier Mills



New 13" Mill Gautier Works



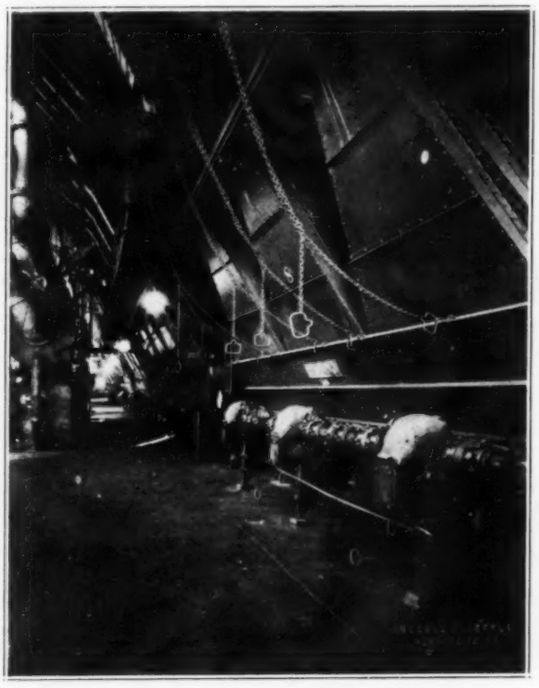
Subway Safety Entrance New Gautier Mills

Roll Shop Gautier Works

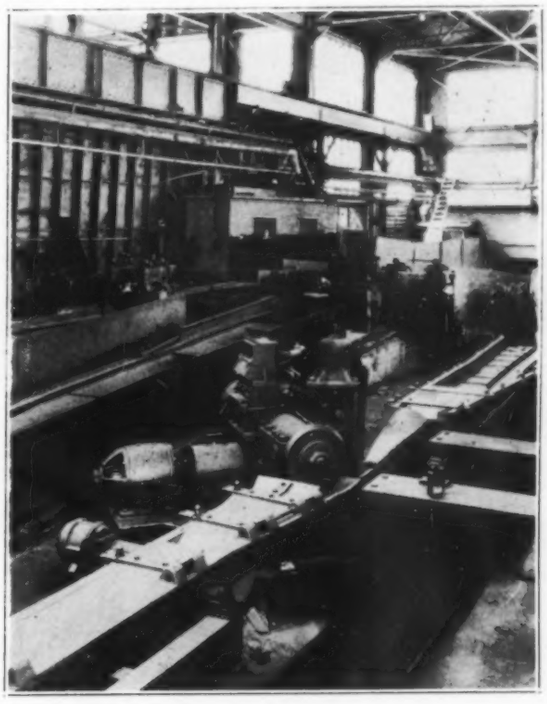
Special Train Leaves Union Station of Pennsylvania Railroad, Pittsburgh, Pa., 8 A. M. Eastern Standard Time

Cambria Plant, Johnstown, Pa.

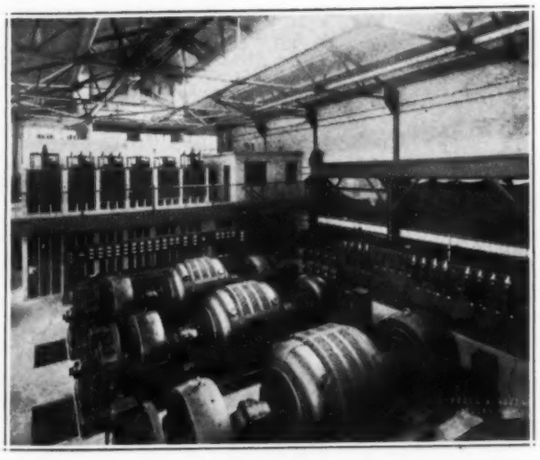
Saturday, September 25th, 1926



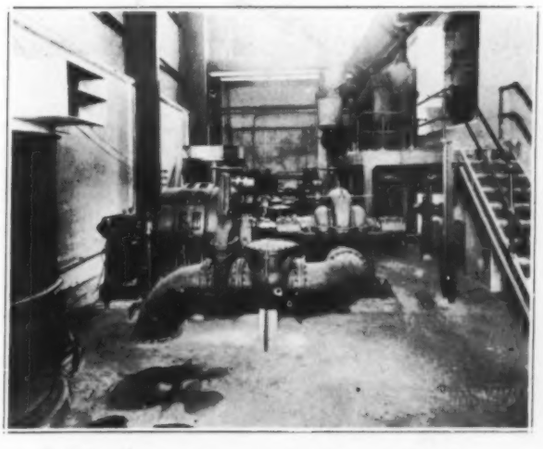
Coal and Stoker Installation New 8,000 H.P.
Boiler House, Franklin Works



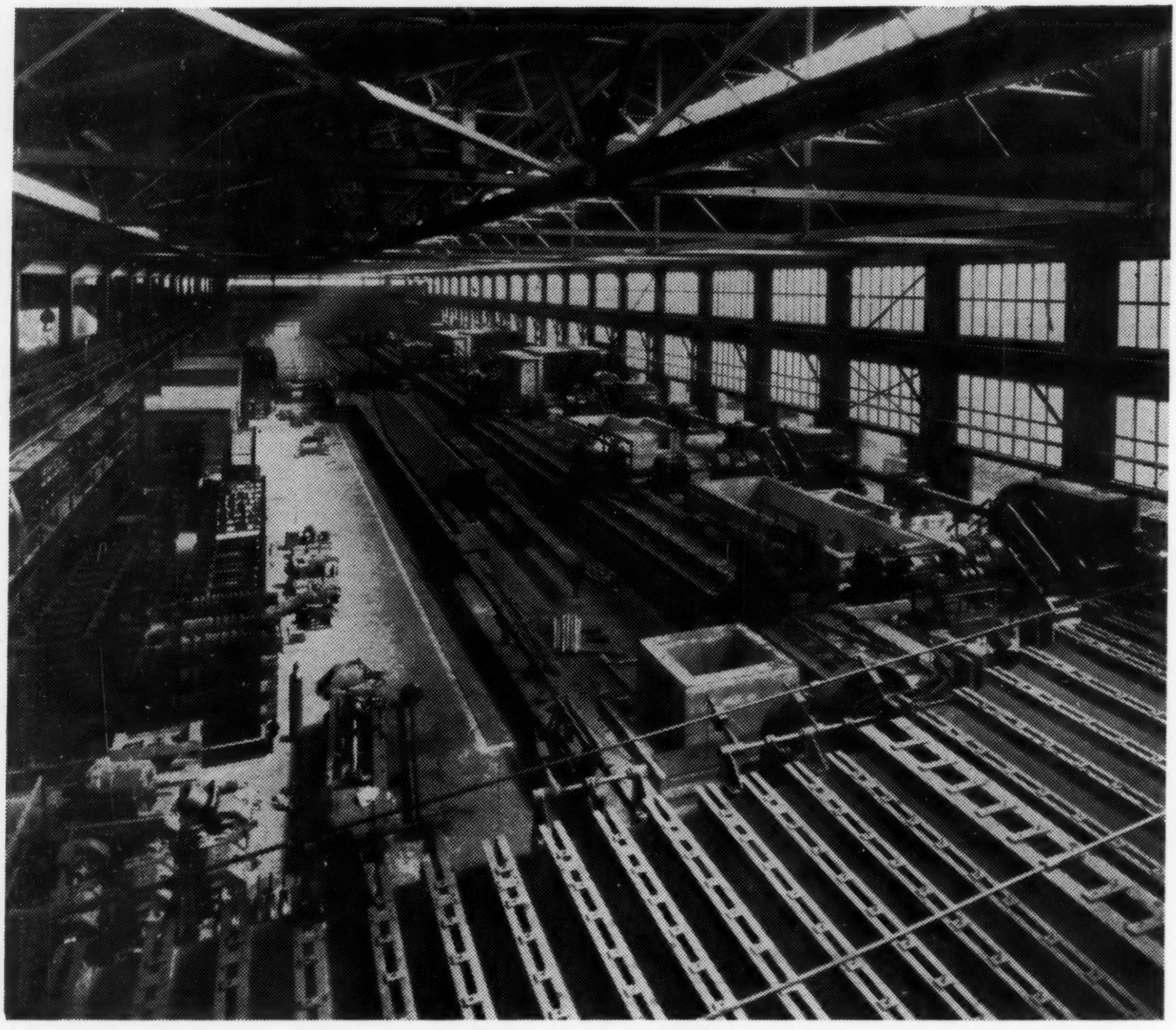
High Speed Shear New 10" Mill, Gautier Works



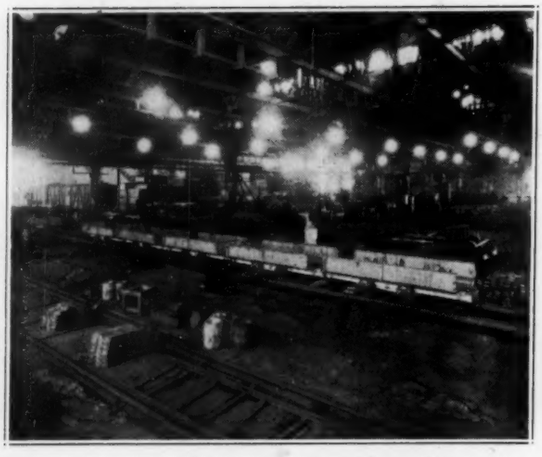
Sub-Station for New Mills, Gautier Works



Circulating Pumps for Spray Pond,
New Power House

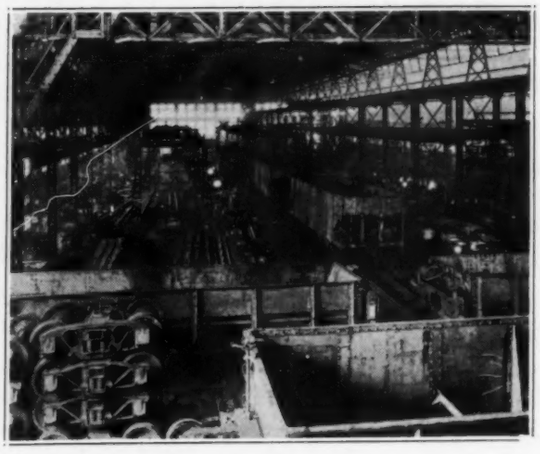


New Thirteen Inch Bar Mill

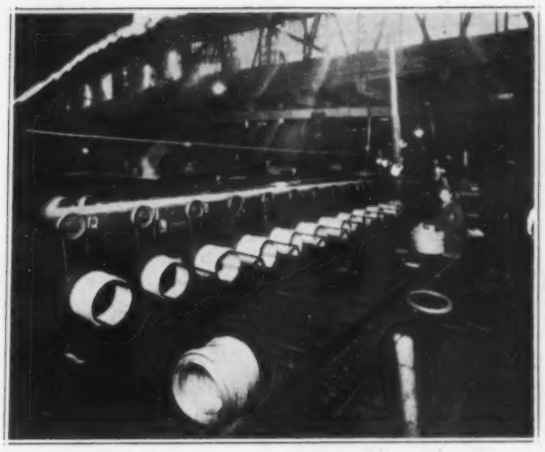


Mine Car Shop, Steel Car Department,
Franklin Works

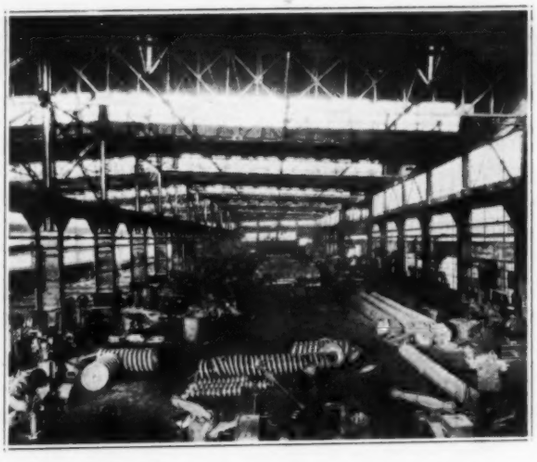
18" Continuous Billet Mill,
Lower Works



Erection Shop, Steel Car Dept.

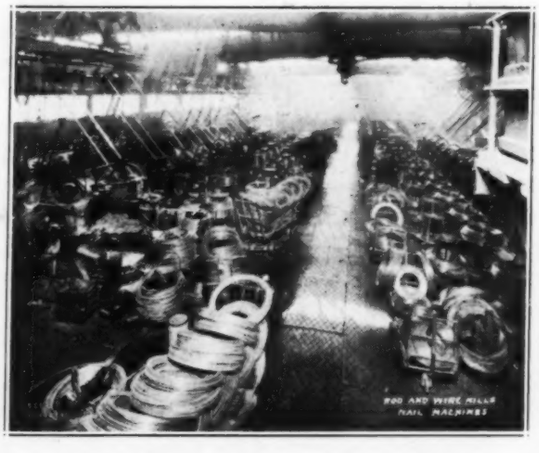


Rod and Wire Works, Galvanizing Dept.



Steel Wheel Finishing Shop, Wheel Works

Frog and Switch Shops, Gautier Works



Rod and Wire Mills, Nail Machines

Rod and Wire Mill, Fence Machines,
Fence and Oil Quenching Tank

CAMBRIA PLANT

Bethlehem Steel Co., Johnstown, Penna.

The Cambria Plant at Johnstown, Pa., is one of the oldest and perhaps one of the best known steel plants in this country. It has an annual pig iron capacity of almost two million tons per year and an annual ingot capacity very close to one million eight hundred thousand tons. It is located in the heart of the bituminous coal region of Pennsylvania and is one of the few steel making plants in the world where coal is taken direct from the mines into the coke ovens without storage or transportation.

The Cambria Plant is operating at the present time ten blast furnaces and in this connection was one of the first steel plants in America to operate a complete automatic skip hoist device. The Cambria Plant also operates four Bessemer converters, twenty-nine open hearth furnaces, fifty heating furnaces, approximately fifty rolling mills and has four hundred and ninety by-product coke ovens, eighty-nine gas producers, five mixers, five cupolas, one hundred and twelve water tube boilers, four thousand motors and a connected load of one hundred and sixty-nine thousand electrical horse power.

The most important part of Bethlehem's rebuilding program at Cambria was the construction of the four new Gautier bar mills, together with the facilities for handling, warehousing and shipping the general products of the Gautier works. These mills with the existing units have a capacity of sixty thousand tons per month of commercial bars, light structural material, mine track accessories, agricultural implement parts and standard and special sections for automobiles and many other purposes.

One of the important units at the plant is the railroad steel freight car department which obtains its requirements of car wheels, axles, beams, plates and other steel materials from other departments within the plant. The capacity of the car department is being increased to over one thousand five hundred cars per month by rearrangement of the shops for quantity production and the construction of a new car paint shop equipped with the most modern appliances. This department operating at capacity will require over two hundred thousand tons of corporation's products per year.

Another important unit is the rod and wire department which has a capacity of twelve thousand five hundred tons per month of rods, wire and wire products of all kinds, including nails and fencing.

The plant also specializes in the manufacture of wheels and axles, rolled steel blanks for gears, flywheels and other circular forgings, sheet bars, slabs, billets, steel mine ties, structural shapes and steel plates.

The equipment of Cambria Plant, at Johnstown, Pa., is as follows:

Blast Furnaces, Lower Division (formerly called Cambria Plant); 4 stacks; B, 91′ 6″ x 21′ 2″, blt. 1853-54, last reblt. 1924; D, 90′ x 22′ 4″, blt. 1853-4, last reblt. 1924; E, 92′ x 24′, blt. 1873-76, last reblt. 1925; F, 86′ 9″ x 22′ blt. 1879, last reblt. 1925. Franklin Division (formerly called Franklin Plant): 5 stacks; G, 85′ 9″ x 22′, blt. 1903-6, reblt. 1914, relined 1924; H, 85′ 9″ x 22′, blt. 1906-07, reblt. 1914, relined 1922; J, 90′ x 22′, blt. 1916, relined 1921; K, 89′ x 22′ 6″, blt. 1916-17, relined 1924; L, 89′ x 22′ 6″, blt. 1917, relined 1924; 35 stoves (4 center-comb. 99′ 6″ x 20′ at B: 23 side-comb. 100′ x 24′ of which 4 each at D, F, J, K, and L and 3 at E: 8 center-comb. 100′ x 24′ of which 4 each at G and H): 18 blowing engines (6 horizontal steam, 6 vertical steam, 5 turbo blowers, 1 gas) 594,000 cfm.; 112 water-tube boilers, 38,780 H. P. furnish power also to Steel Depts. and rolling mills; 5 Heyl & Patterson double-strand pig casting mach.; Dwight & Lloyd (2 strand) sintering plant for flue dust, annual cap., 150,000 tons. By-product coke; Lake ore. Product: bessemer, basic and foundry pig iron, and ferro-manganeses, annual cap., 1,740,000 tons. By-product Coke Dept.: Lower Division, Rosedale, 208 by-product coke ovens (120 Cambria improved 88 Semet-Solvay): Franklin Division, 282 by-product coke ovens (92 Koppers, 190 Cambria; by-product recovery plants and Semet-Solvay benzol plant; annual cap., (490 ovens) 1,848,000 net tons coke; 7,500,000 gals. light oil.

Steel Dept.: Lower Division, blt. 1853, first bessemer steel July 10, 1871, first O. H. steel 1879; 4 bessemer converters (12½-ton); 7 B. O. H. fur. (four 40-ton, three 50-ton); 1 A. O. H. fur. (50-ton); Franklin Division, blt. 1900-01, 21 B. O. H. fur. (sixteen 75-ton, five 100-ton); fuel in O. H. producer gas and tar, 89 gas producers (Morgan, Taylor, Hughes); 5 mixers (one 1,300-ton, one 300-ton, three 250-ton): 5 cupolas for pig iron, 2 cupolas for spiegel. Foundry for gray-iron castings (4,000 tons), ingot stools (14,000 tons) and brass castings (700 tons) for own use and for sale.

Rolling Mill Depts.

Lower Division: eight 1-hole soaking pits; 16-heat. fur.; 48″ 2-h. 1-st. blooming; 40″ 2-h. 1-st. blooming; 22″ 2-h. 4-st. and 1-8″ 2-h. 8-st. cont. sheet bar and

billet; 30″ 3-h. 4-st. structural; 22″ 3-h. 3-st. structural; 28″ 3-h. 3-st. rail; 22″ 2-h. 1-st. axle; axle forge dept.

Franklin Division: 15 soaking pits (nine 1-hole, six 4-hole); 15 heat. fur.; 40″ 2-h. 1-st. blooming; 34″ 2-h. 2-st. universal slabbing; 32″ 2-h. 1-st. blooming; 34″ 2-h. 1-st. billet; 36″ x 134″ 3-h. sheared plate mill; rolled steel wheel dept.; steel freight car dept.; bolt, nut and rivet dept.

Gautier Division: 19 heat. fur.; 28″ 3-h. 1-st. and 22″ 2-h. 1-st. bar; 20″ 3-h. 1-st. and 20″ 2-h. 1-st. bar; 18″ 3-h. 2-st., 14″ 3-h. 5-st. and 14″ 2-h. 1-st. bar; 13″ 3-h. 3-st. bar; 12″ 3-h. 4-st. and 12″ 2-h. 1-st. (No. 1, 12″ bar); 16″ 2-h. 6-st. and 12″ 2-h. 2-st. (No. 2, 12″ bar); 18″ 3-h. 1-st., 10″ 3-h. 6-st. and 10″ 2-h. 1-st. bar; 9″ 3-h. 4-st. and 9″ 2-h. 2-st. (No. 1, 9″ bar); 9″ 2-h. 3-st. cont., 9″ 3-h. 1-st., and 9″ 2-h. 3-st. (No. 3, 9″ bar); 12″ 3-h. 1-st., 8″ 3-h. 3-st. and 8″ 2-h. 2-st. (No. 1, 8″ bar); 12″ 3-h. 1-st., 8″ 3-h. 3-st. and 8″ 2-h. 2-st. (No. 2, 8″ bar); 10″ 2-h. 6-st. and 8″ 2-h. 3-st. (No. 3, 8″ bar); 24″ x 67″ universal plate mill; agricultural implement dept.; frog and switch dept.; splice bar shop; rail anchor shop; shear shop.

TENTATIVE PROGRAM

Special Notice

Special train will leave the Union Station, Pennsylvania Railroad, Pittsburgh, Pa., at 8:00 A. M., Eastern Standard Time

Fill in your card announcing your intentions so that the general arrangements committee will be able to provide for your convenience and comfort.

Make arrangements to attend this trip using the special train. This will avoid all confusion, as the special train will stop at the entrance to the plant; also, all of the guests who take the train will be provided with proper identification tags which will insure them a guide, a luncheon, and the many courtesies that the Bethlehem Steel Company is prepared to offer them that day. Provided enough reservations are made for the special train, half fare rates will prevail.

The Inspection Trip will start about 10:30 A. M., Eastern Standard Time.

The luncheon will be served about 2:00 P. M., Eastern Standard Time.

The Technical Session will start about 2:30 P. M.

The luncheon and technical session will be held at the Johnstown High School.

Dinner will be served about 5:00 P. M.

The official program will be contained in the September issue of the Iron and Steel Engineer.

Association of Iron and Steel Electrical Engineers

FOUNDED 1907.

The object of the Association is the advancement of electricity and other branches of engineering to the Iron and Steel and Allied Industries through the co-operation of its members.

The principal engineering branches that the Association specializes on today are electrical, combustion, safety and mechanical.

The Association has for its members, presidents, executives, operating superintendents and all classes of engineers in the Iron and Steel and Allied Industries.

The Association represents twenty years of engineering service to the Iron and Steel and Allied Industries.

The Association of Iron and Steel Electrical Engineers operates five sections: Birmingham, Chicago, Cleveland, Philadelphia and Pittsburgh.

The Iron and Steel Engineer is the official periodical of the Association and is operated exclusively by the executives and engineers of the Iron and Steel Industry. As a reference and a guide in the Iron and Steel field, it is incomparable.

The Iron and Steel Exposition is an institution operated in connection with the Annual Convention of the Association of Iron and Steel Electrical Engineers. All of the leading manufacturers are represented at the Exposition. The Exposition will be held in June, 1927, at Pittsburgh, Pa.

The Association of Iron and Steel Electrical Engineers operates each year inspection trips to the leading Steel Companies of the United States. The following is a partial list of the Steel Companies who have co-operated with the Association:

The Alan Wood Iron and Steel Co.,
Ivy Rock Plant, Ivy Rock, Penna.

American Steel & Wire Company,
Cleveland, Ohio.

Bethlehem Steel Corporation,
Lehigh Division, Bethlehem Plant, Bethlehem, Penna.
Saucon Division, Bethlehem Plant, Bethlehem, Penna.
Steelton Plant, Steelton, Penna.
Maryland Plant, Sparrows Point, Md.
Cambria Plant, Johnstown, Pa.
Lackawanna Plant, Lackawanna, N. Y.

Carnegie Steel Company,
Clairton Steel Works and Furnaces, Clairton, Penna.
Clairton By Product Coke Works, Clairton, Penna.

Duquesne Steel Works & Furnaces,
Duquesne, Penna.

Edgar Thomson Steel Works and Furnaces,
Braddock, Pa.

McDonald Mills,
McDonald, Ohio.

Ohio Steel Works and Furnaces,
Youngstown, Ohio.

Carpenter Steel Company,
Reading, Penna.

Central Steel & Furnace Company,
Massillon, Ohio.

Donner Steel Company,
Buffalo, N. Y.

Ford Motor Company,
Detroit, Mich.

Harrisburg Pipe and Pipe Bending Co.,
Harrisburg, Penna.

Illinois Steel Company,
Gary Works, Gary, Ind.

Inland Steel Company,
Chicago, Ill.

Lukens Steel Company,
Coatesville, Penna.

National Enameling and Stamping Co.,
St. Louis, Mo.

National Tube Company,
McKeesport, Pa.

Tennessee Coal, Iron & Railroad Co.,
Birmingham, Ala.

Trumbull Steel Company,
Warren, Ohio.

United States Steel Corporation,
Boat Ride up the Hudson River and Dinner at Bear Mountain, New York, N. Y.

Youngstown Sheet and Tube Company,
Youngstown, Ohio.